REHABILITATION OF LANDS STRIPPED FOR COAL *in Ohio*

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G. A. LIMSTROM · · · · · R. W. MERZ
CENTRAL STATES FOREST EXPERIMENT STATION
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BY

G. A. LIMSTROM AND R. W .MERZ

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A. G. CHAPMAN,* Chief, Division of Forest Management Research

J. T. AUTEN,* Forest Soils

RALPH AHLSKOG, Project Leader

Field Personnel - - - Joe A. Gandy, Kenneth Ratcliff, R. D. Lane*

Office Personnel - - Alberta M. Hiatt,* Charles Christian, Karl Chrisemer*

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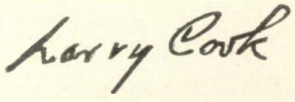
FOREWORD

"Rehabilitation" is not just a big word — it is a word with a big meaning. When we speak of the rehabilitation of an individual it implies more than the return to a job. It signifies as well the development of good character, and a re-establishment in society as a happy and useful citizen. Similarly, this treatise is concerned with more than merely securing a growth on the land stripped for coal in Ohio. It is a comprehensive study of the characteristics and capabilities of these lands, and of the means of developing them into productive additions to the communities in which they lie.

The scientific approach to the rehabilitation of strip lands in Ohio began several years ago when Dr. A. G. Chapman, Chief of the Division of Forest Management for the Central States Forest Experiment Station, U. S. Forest Service, conducted plantings on strip lands which were a part of the Wayne National Forest in southern Ohio. The success of these plantings led to an appropriation by the Congress in 1945 for further forest research on strip lands throughout the Central States region. G. A. Limstrom and R. W. Merz have been responsible for developing this research here in Ohio. Working together closely under Dr. Chapman's guidance, they have learned many things about the strip lands. Now, after approximately five years of this study, they have collected and correlated their findings to date and have compiled them into this practical treatise.

On behalf of President Robert B. Marshall, the directors, members and personnel of the Ohio Reclamation Association, I want to extend to Director Harold L. Mitchell of the Central States Forest Experiment Station our commendation of these members of his staff for the unprejudiced, diligent and intelligent manner in which they have conducted this research. I wish also to express our appreciation for the opportunity we have had to work with them on this project and to cooperate in its sponsorship. We are privileged to publish this valuable work for the benefit of others.



Executive Vice President
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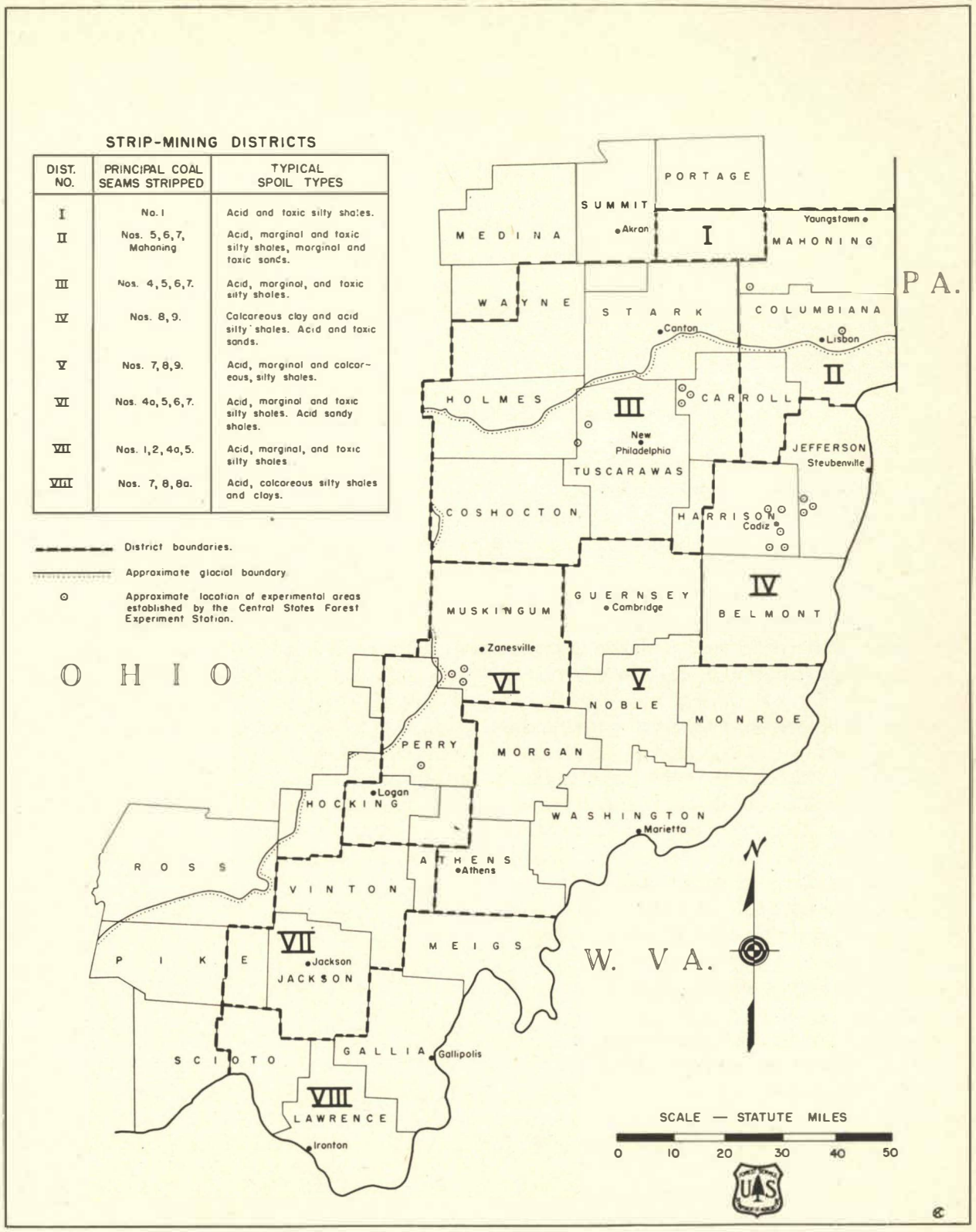

Frontispiece—The coal mining region of Ohio

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G. A. LIMSTROM AND R. W. MERZ

INTRODUCTION

Strip-mining of coal was first reported in Ohio in 1915 (6)[1], when 100,000 tons were produced by this method. Until 1940 the annual production of strip-mined coal never exceeded 4 million tons. Since 1940, however, the rate has accelerated sharply and by 1948 the annual production was reported to have been more than 20 million tons, or 52.4 per cent of the total amount mined (7). This increase in stripping operations was brought about mainly by improved market conditions for coal, and by technological developments which permitted the recovery of coal near land-surfaces. Shallow deposits of coal are not generally minable by underground methods.

A reconnaissance made in 1946 and 1947 disclosed a total of 36,213 acres of strip-mined lands in the state. This estimate includes the areas from which the coal was removed and adjacent areas upon which some of the overturned material was placed. It was based on data obtained from county records, reports submitted to the State Bureau of Mines, aerial photographs, and maps from mining companies. As a further check each strip-mined area was given a field examination.

From this reconnaissance also came information on the reclamation possibilities of strip-mined land. The data collected will serve as a basis for future studies in plant growth on spoil banks and as a basis for land-use planning. More than 90 percent of the strip-mined lands in the state was found to be in such condition that it could be put to some productive use within a few years after mining. A part of the remaining 10 percent may eventually become productive.

Site conditions on strip-mined lands are so varied and complex that only a few general rules can be made for their rehabilitation. The purpose of this publication is to describe these varied conditions in detail, to point out possible uses for these lands, and to make forest planting recommendations on the basis of present information.

1 Figures in parentheses refer to publications mentioned in "Literature Cited" on Page 41.

Texture of Spoils

Less than 10 percent of the strip-mined lands in the state is composed chiefly of sand, sandy shales, and sandstone (fig. 1). About 42 percent consists mainly of silty shales and loams. The remaining areas, 48 percent, are composed chiefly of clay and limestone, most of which occur in Belmont, Harrison, and Jefferson Counties.

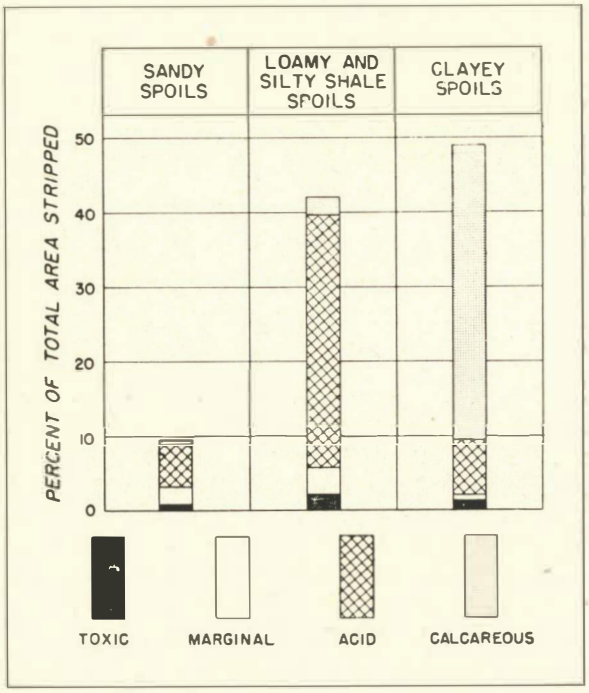

Figure 1.—Proportion of strip-mined area in Ohio in acidity and texture classes, 1946.

Sandy spoils are loose, are well aerated, and have a low water-retaining capacity. With some exceptions the massive sandstone commonly associated with these spoils disintegrates and settles rapidly; most of these lands are plantable one to two years after stripping.

Spoils consisting chiefly of silty shales and loams offer good physical conditions for plant growth. They usually contain enough silt and clay to provide good moisture conditions, and enough shale to permit good aeration and internal drainage. The large stones associated with these spoils are chiefly thick-bedded shales and massive sandstone. Some shales disintegrate at a slightly slower rate than the sandstone, but the rate of weathering is rapid enough to permit planting within one to two years of stripping.

Clay spoils have a high water-retaining capacity and frequently develop compact, impervious soils with poor aeration and internal drainage. Oftentimes, however, a high proportion of stone in the spoil mixture tends to improve aeration and drainage. Some of the massive limestone commonly found on clay spoils in the state is hard and decomposes very slowly. Although these spoils can sometimes be planted within one or two years after stripping, better results at lower costs are often obtained by waiting three to five years.

Acidity of Spoils

Less than four percent of the area of strip-mined land in the state was toxic (4) and therefore not plantable. Toxic spoils are those with pH values less than 4.0 over more than 75 percent of their surface. Some of these lands will become suitable for plant growth after sufficient time has elapsed for the leaching of the toxic substances in the spoil material. Less than 2500 acres, or 6.5 percent was classed as marginal. This area includes those banks whose surfaces are toxic in patches aggregating 50 to 75 percent of their total stripped area. The nontoxic portions of marginal spoils are plantable, but are so small or scattered that most plantings on these areas will be desirable only for soil improvement, erosion control, or aesthetic purposes.

More than 17,000 acres, or 47 percent of the area of strip-mined land, was acid. These areas, where the pH ranges generally from 4.0 to 6.9, are suitable for the growing of a wide variety of plants and are especially adapted to forest planting. More than 40 percent of the strip-mined area is calcareous and therefore suitable

for plant growth. Most of the spoil banks in the state that may be suitable for some agricultural use are calcareous. They are also adapted to the growing of many hardwoods and some conifers.

In Ohio banks of mixed acidity are rare. The reconnaissance disclosed only 216 acres in this class, which accounted for 0.6 per cent of the area of stripped land. On banks with mixed acidity the pH range is so varied that they cannot be classified as toxic, marginal, acid, or calcareous.

Age Classes of Spoils

More than one-half of the total area of strip-mined land in the state (19,587 acres) is the result of stripping operations during the period 1942 to 1946 (table 1). Even an approximate estimate of the area of future coal-stripping operations in the state would be difficult to make and largely speculative. Although the location of outcrops of the principal coal seams is well known, their quality and thickness vary to such a degree that strip-mining is not practicable in all areas where shallow deposits occur. Detailed prospecting data are necessary before the feasibility of strip-mining an area can be determined. Future stripping will depend to a greater degree upon social and economic conditions, legislation governing these operations, and technological developments than upon the extent of coal outcropping in the state.

Present Cover and Use Of Strip-Mined Lands

More than half the area of strip-mined lands in Ohio was devoid of vegetation at the time of the reconnaissance (table 2). This area has largely been stripped during the past 5 to 10 years. More than 8,500 acres has seeded naturally to grasses, weeds, and other herbs; part of this area is pastured. Approximately 7,000 acres supports successful forest plantations (fig. 2) and 3,000 acres is in permanent pastures and orchards. Almost 2,000 acres have seeded naturally to potentially merchantable trees and need no further rehabilitation measures.

REHABILITATION PROBLEMS

Very few general rules can be made for the rehabilitation of strip-mined lands. The diversity of site conditions is so great that almost every strip-mined area presents a combination of factors that requires special consideration. The intended use of each area will determine the intensity of road systems required, and the relative extent of mined and unmined land has an important bearing on the proper land use for the area.

Diversity of Site Conditions

The most important site conditions affecting plant growth are spoil texture and acidity, the proportion of soil to stone, and spoil bank stability and topography. These site conditions vary widely on the stripped lands in Ohio, chiefly because of differences in coal seams mined, locality, composition and thickness of the overburden, and mining methods.

In Ohio as many as 18 different coal seams have been mined by stripping methods (table 3). The texture and acidity of strip-mined lands in the state vary considerably with the coal seam (figs. 3 & 4). More than 90 percent of the area of spoils resulting from the mining of the No. 8 Pittsburgh coal seam is calcareous and clayey, whereas spoils resulting from the mining of the No. 5 Lower Kittanning coal seam are predominately acid and loamy and contain a relatively high proportion of silty shale. More than 20 percent of the area of spoils resulting from the mining of the 4a Clarion coal seam is toxic, whereas the mining of the Mahoning coal has resulted in little or no toxic spoils.

Texture and acidity of spoils also vary by locality. Typical spoils resulting from the mining of No. 8 Pittsburgh coal, for example, are composed mainly of clay and limestone. In certain locations in the

Table 1.--Area of strip-mined land in Ohio by county and by age class of spoils, 1946

County	Date of estimate		Years since stripping						Total
			1-5	6-10	11-15	16-20	21-25	26-30	
	Month	Year	Acres						
Athens	Oct.	1946	517	0	0	0	68	0	585
Belmont	Aug.	1947	1,704	48	0	0	0	53	1,805
Carroll	Sept.	1946	506	372	0	0	43	0	921
Columbiana	June	1946	2,102	1,081	240	86	0	0	3,509
Coshocton	Jan.	1947	498	0	0	0	0	0	498
Gallia	Sept.	1946	5	23	0	0	0	0	28
Guernsey	Jan.	1947	153	0	18	0	0	114	285
Harrison	Dec.	1945	3,627	762	2,777	700	765	0	8,631
Hocking	Dec.	1946	471	114	0	0	0	0	585
Holmes	Dec.	1946	182	61	0	0	0	0	243
Jackson	Sept.	1946	193	121	46	0	0	0	360
Jefferson	Nov.	1945	3,192	871	641	1,015	371	162	6,252
Lawrence	Sept.	1946	32	0	0	0	0	0	32
Mahoning	July	1946	248	367	0	0	0	0	615
Meigs	Sept.	1946	55	0	0	0	0	0	55
Morgan	Dec.	1946	75	0	0	0	0	0	75
Muskingum	Aug.	1947	397	48	0	543	0	296	1,284
Noble	Dec.	1946	276	0	0	0	0	0	276
Perry	Dec.	1946	1,561	264	775	279	0	0	2,879
Portage	July	1946	178	0	8	0	0	0	186
Stark	Aug.	1946	1,272	867	21	160	0	0	2,320
Tuscarawas	Dec.	1946	1,877	1,636	104	0	0	352	3,969
Vinton	Sept.	1946	398	354	0	0	0	0	752
Washington	Dec.	1946	8	0	0	0	0	0	8
Wayne	Aug.	1946	60	0	0	0	0	0	60
Total	--	--	19,587	6,989	4,630	2,783	1,247	977	36,213

Table 2.--Area of strip-mined land in Ohio by county and cover class, 1946

(In acres)

County	Barren	Natural vegetation			Forest plantations 1/	Other cover 2/	Total
		Herbs & grasses	Shrubs	Trees			
Athens	477	64	0	44	0	0	585
Belmont	1,164	564	0	17	7	53	1,805
Carroll	726	180	0	4	11	0	921
Columbiana	2,437	892	3	93	80	4	3,509
Coshocton	493	5	0	0	0	0	498
Gallia	16	10	0	2	0	0	28
Guernsey	167	83	12	5	18	0	285
Harrison	3,233	3,841	0	225	803	529	8,631
Hocking	477	83	0	25	0	0	585
Holmes	194	4	0	0	45	0	243
Jackson	303	15	0	42	0	0	360
Jefferson	3,314	1,329	0	842	342	425	6,252
Lawrence	32	0	0	0	0	0	32
Mahoning	519	95	0	1	0	0	615
Meigs	51	4	0	0	0	0	55
Morgan	74	1	0	0	0	0	75
Muskingum	726	117	40	131	270	0	1,284
Noble	251	25	0	0	0	0	276
Perry	2,014	494	0	241	130	0	2,879
Portage	174	11	0	1	0	0	186
Stark	1,710	547	1	18	44	0	2,320
Tuscarawas	3,377	228	3	6	355	0	3,969
Vinton	660	79	0	13	0	0	752
Washington	8	0	0	0	0	0	8
Wayne	57	3	0	0	0	0	60
Total	22,654	8,674	59	1,710	2,105	1,011	36,213

1/ Since 1946 a total of 3,900,000 trees have been planted on strip-mined lands in Ohio. This represents an additional area of about 4,900 acres in forest plantings.

2/ Pastures and orchards. Since 1946 an additional 2,200 acres have been seeded to grasses and legumes.

Figure 2.—Fourteen-year-old pine and hardwood plantations on strip-mined lands in Muskingum County. A.—Mixture of red, jack and Scotch pines. B.—Same pine plantation, to left of pond used for recreation; to the right of pond is a planted and natural stand of mixed hardwoods.

Table 3.--Area of strip-mined land in Ohio by coal seam and by texture and acidity classes, 1946

(In acres)

Coal seam	A. Sandy spoils					B. Loamy & silty shale spoils					C. Clayey spoils					Total
	Toxic	Marginal	Acid	Calcareous	Mixed	Toxic	Marginal	Acid	Calcareous	Mixed	Toxic	Marginal	Acid	Calcareous	Mixed	
No. 1 - Sharon	0	0	0	0	0	0	158	34	0	0	0	0	0	0	20	212
No. 2 - Quakertown	0	0	0	0	0	0	0	36	0	0	0	0	0	0	0	36
No. 3a - Upper Mercer	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	8
No. 4 - Brookville	0	0	0	0	0	0	0	36	45	7	0	0	0	0	0	88
Ogan	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	8
No. 4a - Clarion	0	57	0	0	0	166	59	238	13	0	0	19	31	0	0	583
No. 5 & 6 - combined spoils	0	0	0	0	0	0	130	866	0	0	13	0	106	0	0	1,115
No. 5 - Lower Kittanning	18	45	22	2	0	151	279	4,447	90	0	243	17	482	38	0	5,834
No. 5a - Strasburg	0	0	30	0	0	0	0	0	0	0	0	0	0	0	0	30
No. 6 - Middle Kittanning	127	20	289	0	101	188	171	3,024	0	0	194	47	1,513	0	0	5,674
No. 6a - Upper Kittanning	0	0	0	0	0	0	0	45	0	0	0	0	0	0	0	45
Lower Freeport	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	6
No. 7 - Upper Freeport	46	378	1,204	0	0	140	230	2,368	0	0	0	0	138	0	11	4,515
Mahoning	0	0	320	0	0	0	0	452	21	0	0	0	0	0	0	793
Harlem	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	5
No. 8 - Pittsburgh	0	383	93	0	0	0	91	201	652	0	39	37	219	13,530	71	15,316
No. 8a - Redstone	0	0	0	0	0	0	4	40	0	0	0	0	0	0	0	44
No. 9 - Sewickley	0	0	223	0	0	66	155	472	90	0	0	75	164	656	0	1,901
Total	191	883	2,181	2	101	717	1,277	12,275	911	12	489	195	2,653	14,224	102	36,213

northern and eastern portions of Jefferson County, however, the limestone is replaced by massive sandstone and sandy shale with corresponding changes in spoil type from a calcareous clay to an acid sand.

Some of the materials overturned in stripping operations contain iron-sulphur compounds, which upon exposure to air are oxidized to sulphuric acid. It is this acid which accounts for most of the toxicity in spoil material. The iron-sulphur compounds usually occur both in the clay below a given coal seam and in the pyritic shale just above it.

It has already been shown that the occurrence of toxic spoils varies a great deal by coal seam (fig. 4). This occurrence varies also by localities for each coal seam. An example of this kind of variation is found in Athens County in the No. 7 Upper Freeport coal seam. South of U. S. Highway No. 33 in York township three to four feet of shale immediately overlying this coal seam is extremely toxic. The resulting spoils in this locality are highly toxic. On areas examined north of this highway, where less than one foot of toxic shale occurs over this seam, toxic conditions are negligible.

Where the zone of toxicity is clearly defined in the overburden, the area of toxic spoils may be reduced by placing this material at the bottom of the banks. Toxic conditions existing on spoil banks make them very difficult to reclaim. An enormous quantity of lime would be required to neutralize toxic materials. The most practical solution appears to be to postpone rehabilitation until the gradual leaching of the acid has made the area plantable.

To impound water for recreational and fish-propagation purposes the surface should be maintained at a level higher than the toxic strata found in the adjoining high-wall.

The proportions of soil-sized particles and stone also has a bearing on the prospective uses of these lands. This proportion may affect the tree species to be planted, and may determine the feasibility of seeding and cultivating for agricultural uses. Serious erosion occurs mainly on spoils with a high proportion of silt and clay, and on banks of rather loose consistency. Strip-mined areas vary considerably in the proportion of soil to stone on spoil surfaces. The important reasons for

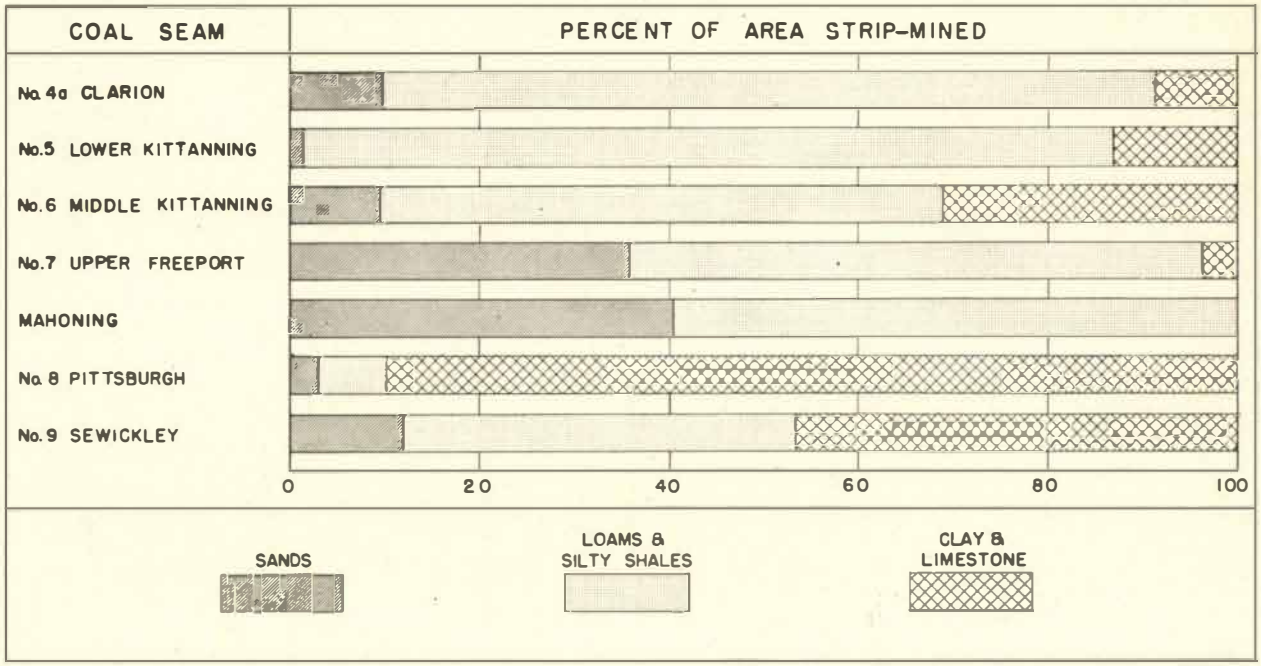

Figure 3.—Proportion of the strip-mined area of each of the principal coal seams in three texture classes, 1946.

this variability are the relative thicknesses of soil and rock strata overturned in the stripping operation and the method of mining. In southeastern Ohio, where many of the hillsides have been subject to severe erosion, the soil mantle is so thin that it contributes little soil-sized material to the spoils. Banks found in valleys often contain much more soil because of the deep alluvium usually found in these situations. Along the northern fringe of the coal mining region of the state glacial material has also contributed much soil to strip-mined lands.

The composition of rock strata overturned in the stripping operation and the rate of rock weathering influence the proportion of soil-sized particles in spoils. Mud shales, some of the silty shales, and the soft sandstones disintegrate rapidly. On the other hand overburden composed mainly of hard, bony, silty shales such as commonly overlie the No. 7 and Mahoning coals in Columbiana County, breaks down into soil very slowly. Some of the limestones also weather very slowly.

Methods of mining may also alter the proportion of soil to stone on spoil surfaces. Where feasible it may be desirable to adapt mining techniques so as to place more soil and rapid soil-forming stones on the tops of banks. The acidity of these strata should, however, be considered before altering normal practice to improve soil conditions.

The diversity of topographic conditions on strip-mined lands and their stability should also be recognized. Spoils should be reasonably stabilized or "settled" before trees are planted. Banks with steep slopes containing a high proportion of loose sliding stone and shale are slow to stabilize; on these sites planting might better be postponed until bank conditions are more stabilized. Where stripping is done on slopes with more than a 60 percent gradient and where high spoil banks with slopes exceeding 70 percent are formed, land-slides may occur. Slipping frequently occurs where there is a definite cleavage between the spoil mass and the earth beneath. This cleavage is often indicated by water seepage. Observations to date show that most slipping occurs within a few years after mining. Where this is likely, planting should be postponed for four or five years after stripping. Unmined lands below these banks should not be planted

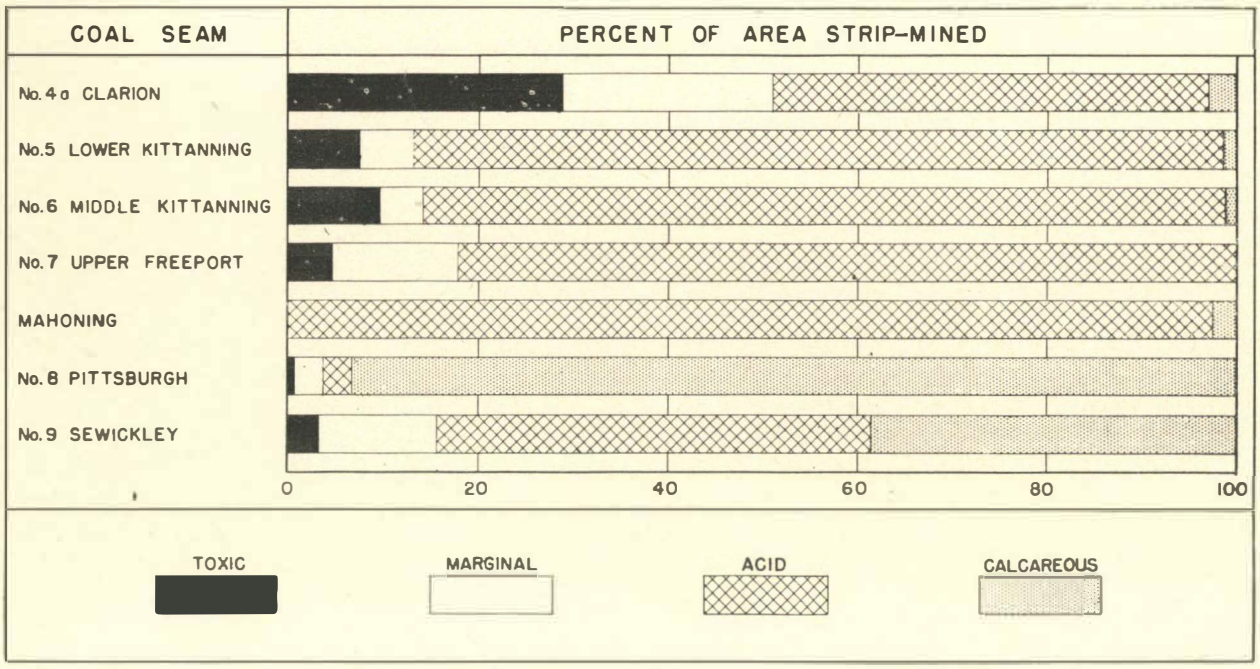

Figure 4.—Proportion of the strip-mined area of each of the principal coal seams in four acidity classes, 1946.

until the danger of slipping has passed.

The height of banks and the intensity of grading are important factors to be considered in foresting strip-mined lands. High banks, those with vertical distances greater than 20 feet from the bottom of the ridge to the crest, are likely to be drier on the upper slope than on the lower. This difference may be sufficient to affect the choice of tree species for planting on these slopes. High, steep ridges are also less suited to grazing use.

The grading of strip-mined lands has a variable effect on tree growth, which depends upon the texture of spoil material and the degree of compaction caused by the machinery used. Experiments initiated in 1946 are beginning to show trends that may within a few years prove to be significant. The results to date indicate no beneficial effects of grading on survival and growth of forest plantations. On the other hand, on banks composed chiefly of clay—typical of soils resulting from the mining of the No. 8 Pittsburgh coal—adverse effects on the growth of some species have been observed.

Access Roads

The need for roads to facilitate the planting, maintaining, and harvesting of the crop should be considered in planning the development of strip-mined lands. The road systems established for coal mining are far more intensive than those usually maintained for timber production. Very few if any additional access roads are needed to protect and harvest forest products on strip-mined lands in Ohio. Ordinarily any existing road system that permits the driving of a loaded truck to within one-fourth mile of any point on a strip-mined area is adequate for forest protection and timber harvesting. Where the intensity of existing road systems does not meet this requirement, it perhaps would be economical in the long-run to construct simple truck-trails before undertaking any other developmental work. These should be located where they will offer the greatest utility at lowest construction and maintenance cost. On some areas this will be in the bottom between ridges and on others on the ridgetops.

Land-Use Planning

The management of strip-mined lands should be coordinated with the planned use of adjacent unmined land (2). Unmined areas on some tracts may be so affected that their former use is no longer practicable (fig. 5). Such areas should per-

Figure 5.—An example of land-use planning; this old field has been furrowed along contours in preparation for tree planting the following spring. Adjacent spoil bank will be planted at the same time.

haps, with due regard for differences in site conditions, be used for the same general purpose as that intended for the strip-mined lands. Conversely, small areas of stripped lands surrounded by large unmined areas may be devoted to the same uses as the unmined areas if site conditions permit, or may be used for specialty purposes such as the production of Christmas trees, fence posts, or mine props. In other words, the relative proportions of stripped and unstripped lands and their differences in site conditions should be a major consideration in the formulation of land-management plans.

POSSIBLE USES OF STRIP-MINED LANDS

Most of the uses to which strip-mined lands are adapted fall into three general classes: (1) forestry, (2) recreation and wildlife, and (3) agriculture. Other uses, such as for industrial or residential purposes, are of minor importance except near municipalities and along railroads and highways.

Forestry Possibilities

Most of the strip-mined lands in Ohio are best suited for forestry. In addition to the production of wood forests help control erosion, improve soil, conserve water, and provide recreational opportunities. Most of these lands are particularly adapted to the growing of Christmas trees, fence posts, mine props, pulpwood and timber. Although definite yield data are not yet available good crops of Christmas trees can be expected within five years, and posts, props, and pulpwood within 15 to 20 years. The production of sawlogs will require a much longer period of time. By the use of mixed plantings and selective thinnings species and trees of highest quality can be retained for the production of sawlogs, while others can be cut at an early age for posts, props, and pulpwood. Where seed trees are adjacent to stripped areas these lands are often reforested naturally (fig. 6). Areas seeding naturally with desired species do not need special reclamation measures. Because these conditions do not exist on many strip-mined lands in Ohio, planting of trees on a large scale will be necessary.

Recreation and Wildlife Possibilities

Many strip-mined areas in the state offer excellent opportunities for recreational development. In planning the use of these lands for picnicking, bathing, and fishing one of the first considerations is the feasibility of impounding enough water suitable for these purposes. If toxic material appears in the adjacent high-walls and if it is not possible to maintain the water level above these strata, periodic liming of water may be necessary. Evidence is also increasing to show that strip-mined lands provide good habitats for game birds and mammals. Large-scale forest planting, supplemented by the planting of trees and shrubs valuable for game foods, will no doubt improve the hunting on these lands.

Agricultural Possibilities

Agricultural use of strip-mined lands is contingent chiefly upon the stoniness of spoil surfaces, upon their acidity and texture, and upon their physiographic characteristics. Spoils containing a large proportion of hard, slowly weathering stones limit the use of farm machinery and may affect the growth of some crops. Many grasses and legumes such as sweetclover require calcareous soil, while others such as certain species of lespedeza and alsike clover tolerate some acidity (5). Steep slopes and the typical saw-toothed configuration of spoil ridges also limit the use of farm machinery. Furthermore the cost of grading must be weighed against prospective returns before it is undertaken. The cost of "striking off" ridgetops for access roads does not appear to be prohibitive in those areas where spoil banks are suitable for agricultural use.

Calcareous spoils have been successfully developed for grazing by seeding to

Figure 6.—Natural forest of sycamore established on strip-mined land in Jackson County. The average age of trees is 14 years, height 25-30 feet, and diameter breast high 2 to 3 inches. A.—General view of the stand. B.—Interior view of the same stand.

grasses and legumes. A number of stripped areas in Belmont, Harrison and Jefferson Counties have been used as pastures. In Illinois the livestock yields on some of these lands are high (3). Seeding by airplane is past the experimental stage and is the cheapest method for obtaining a good cover of grasses and legumes on large areas. Recently the use of helicopters for seeding and spraying has proved feasible.

A limited area of strip-mined land bears orchards and vineyards. More research on horticultural possibilities is needed, as data on costs and returns for this use are still too meagre to encourage extensive use of spoils for this purpose.

FOREST PLANTING AND SEEDING EXPERIMENTS

A number of forest-planting experiments have been established on strip-mined lands in Ohio. These were initiated to supplement observations on existing plantations and to solve problems encountered in rehabilitating these lands. The experiments include studies of: (1) the species suitability to site, (2) the effects of grading spoil banks on seedling survival and growth, (3) planting methods, (4) underplanting methods, (5) mixed plantings, (6) seasons for planting, and (7) direct seeding. The first experimental plantings were made in 1937, 1938, and 1939 on what is known as the Kehota tract in Perry County (1). Since 1946 a large number of tests has been established in the counties in the northern half of the coal-mining region, where most of the stripping is located (see frontispiece).

Species Suitability to Site

Four experimental plantings were established to study the suitability of species to site. These include: (1) the plantings on the Kehota tract in Perry County, where the spoils consist mainly of acid silty-shale loams with much thick-bedded shale and lesser proportions of sandstone, and where the range of acidity is generally between a pH of 5.0 and 6.9; (2) experiment No. 6 in Jefferson County, where the spoils consist almost entirely of calcareous clay and limestone, with lesser proportions of silty and sandy shales; (3) experiment No. 7 in Holmes and Tuscarawas Counties, where the spoils are composed mainly of acid silty shales, where toxic patches are numerous, and where the pH range is generally from 3.0 to 5.0; (4) experiment No. 8 in Mahoning County where the spoils are also composed of silty shales with some clay and glacial till, and where the acidity ranges generally from a pH of 6.5 to 7.8.

The results of the latest examinations of these plots are given in table 4. With the exception of black locust the growth of hardwoods on these sites has been exceedingly slow. These are pure plantings, however, and do not represent growth possibilities of those species when mixed with black locust or underplanted in black locust stands. Most of the losses and differences in growth rates on these areas are attributed to differences in spoil acidity, spoil consistency, and poor planting stock. For some species survival and growth differ significantly with slope and aspect. Density of vegetational cover also accounts for some of the losses on Experiment No. 6.

Effects of Acidity on Survival and Growth

At the end of the first growing season the mortality of planted trees due to spoil toxicity was 2 percent for Experiment No. 6, 8 percent for Experiment No. 7, and 10 percent for Experiment No. 8. The rate of mortality from this cause was the same for all species and age-classes of stock. The exact lethal acidity point for each species has not yet been determined, but in forest planting practice those spoils having pH readings of less than 4.0 should be considered non-plantable. Planting on toxic areas can be avoided by making frequent pH determinations as planting

Table 4.--Comparative survival and total heights of trees planted on four spoil bank areas in Ohio

Species	Age class of planting stock	Age of plantation	Kehota tract: Silty-shale loam, pH 5.0 - 6.9, No. 6 coal seam		Experiment No. 6: Calcareous clay, limestone, pH 7.0+, No. 8 coal seam		Experiment No. 7: Silty-shale loam pH 3.0 - 5.0, No. 5 coal seam		Experiment No. 8: Silty shale loam pH 6.5 - 7.8, No. 5 coal seam	
			Survival	Average height	Survival	Average height	Survival	Average height	Survival	Average height
			Percent	Feet	Percent	Feet	Percent	Feet	Percent	Feet
Pines:										
Red	2 - 0	2	--	--	76	.4	64	.5	76	.4
	3 - 0	2	--	--	81	.5	52	.6	65	.6
White	2 - 0	2	--	--	71	.4	49	.4	66	.4
	3 - 0	2	--	--	70	.6	55	.6	87	.7
	2 - 2	2	--	--	82	.6	88	.8	74	.9
Pitch	1 - 0	8	84	9.0	--	--	--	--	--	--
	2 - 0	1	--	--	95	.4	82	.4	--	--
		8	90	9.8	--	--	--	--	--	--
Shortleaf	1 - 0	8	94	10.6	--	--	--	--	--	--
	2 - 0	1	--	--	79*	.4	66*	.4	--	--
		8	92	10.3	--	--	--	--	--	--
Eastern red cedar	1 - 0	7	85	3.0	--	--	--	--	--	--
Black locust	1 - 0	7	78	25.0	--	--	--	--	--	--
	1 - 0	2	--	--	86	7.1	85	3.9	84	5.5
Yellow poplar	1 - 0	7	67	2.6	--	--	--	--	--	--
		2	--	--	17*	.3	38*	.8	39*	.4
		1	--	--	82	.8	61	.6	--	--
	1 - 1	2	--	--	37*	.5	37*	.8	52*	.6
Osage orange	1 - 0	2	--	--	17	1.0	51	1.2	70	.9
White ash	2 - 0	2	--	--	42	1.4	72	1.1	75	1.2
Green ash	1 - 0	7	98	2.7	--	--	--	--	--	--
		1	--	--	87	.8	83	.7	--	--
Cottonwood	Cuttings	1	--	--	54	.7	58	.8	--	--
	1 - 0	1	--	--	36*	1.0	39*	.8	--	--
Red oak	1 - 0	7	94	3.0	--	--	--	--	--	--
		1	--	--	31*	.6	45*	.5	--	--
White oak	1 - 0	1	--	--	58*	.6	53*	.9	--	--
Basswood	1 - 0	1	--	--	77	.8	74	.7	--	--
Silver maple	1 - 0	5	98	3.3	--	--	--	--	--	--
		1	--	--	90	.6	96	.9	--	--
Sycamore	1 - 0	5	96	3.5	--	--	--	--	--	--

*Planting stock was of poor quality.

proceeds. Some spoils, however, appear plantable but contain toxic materials at a depth of only a few inches. Occasional sampling to depths of 12 to 18 inches is desirable.

Acidity also has an important effect on rate of growth, but the experimental plantations established to date are not old enough to show marked differences for most species. The growth of black locust, however, has been rapid enough to show the effect of acidity on height increment. The average height of this species on one area, for example, was 3.6 feet at two years of age, whereas on another the average was 7.1 feet (fig. 7). Acidity of the spoils in the former area was generally in the pH range of 3.0 to 5.5 in contrast to a range of 6.8 to 7.8 for the latter.

Effects of Spoil Consistency On Survival and Growth

The experimental areas are too similar with respect to spoil texture (the proportion of soil-sized particles and stones) to illustrate the importance of this factor on survival. However, there are differences in their consistency which partially account for differences in erosion losses. Banks having a relatively large quantity of shale (Experiments 7 and 8, table 4) are usually of a loose consistency with practically no adherence or aggregation of individual particles of shale and soil. They are subject to erosion and siltation, and in some instances seedlings have been damaged by shale particles blown by strong winds. Banks composed mainly of clay and limestone (Experiment No. 6) are much more compact; soil particles and stones adhere tightly to each other, and form a massive or aggregate structure which permits little or no internal drainage. Seedling losses from erosion on these sites (Experiment No. 6) were negligible during the first year after planting, whereas a mortality of 7 and 4 percent, respectively, was sustained from this cause on the shale banks.

No experimental data are yet available to illustrate the effects of spoil texture and consistency on the growth of plantations. General observations indicate better growth on shaly loams having a high proportion of soil than on compact impervious clay spoils.

Effects of Slope and Aspect On Survival and Growth

The effects of aspect on the survival and growth of trees are generally the same on strip-mined lands as on unstripped land. On unleveled banks four broad topographic classes, based on differences in growth are recognized: (1) north and east slopes; (2) south and west slopes; (3) tops of ridges, and (4) bottoms between ridges.

Except for black locust, most of the trees planted on the experimental areas are too young to show appreciable height differences among these topographic classes. On two areas the growth of this species

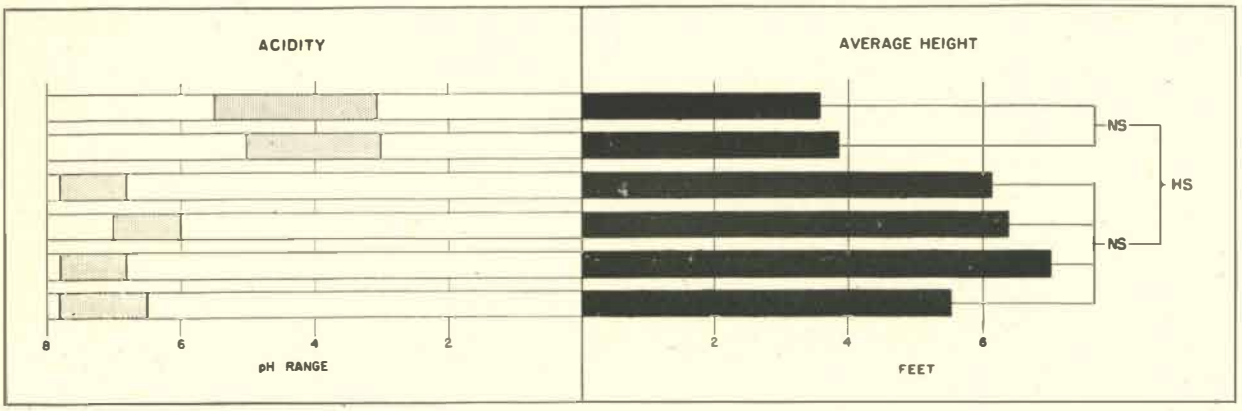

Figure 7.—Relation between height of black locust two years after planting and acidity of spoil surfaces on six experimental areas in Ohio, 1947. NS denotes no significant difference in total height; HS denotes high significance.

has however been rapid enough to provide a real contrast three years after planting (table 5). The trees are about 2 feet higher on the slopes than on the ridges—a growth differential of high statistical significance. The average height of trees growing in the bottoms is only a half foot greater than on the slopes.

Table 5.--Height of 3-year-old black locust on two similar spoil banks by topographic class, 1948

Topographic class	Experiment No. 3	Experiment No. 6
	Feet	Feet
North and east slopes	10.8	10.7
South and west slopes	10.8	10.6
Tops of ridges	8.8	8.4
Bottoms between ridges	11.1	11.3
Average	10.6	10.5

These varying rates of growth are attributed mainly to the differences in moisture conditions and length of growing season. Slightly better moisture conditions on the north and east slopes seem to compensate for a slightly longer growing season on the south and west slopes. The results shown in table 5 suggest the desirability of planting dry-site species on the tops of ridges and upper slopes, and of planting good-site species, such as yellow poplar and black walnut, on the bottoms and lower slopes.

The Effect of Ground Cover On Survival and Growth

The effects of existing vegetation on survival and growth of forest plantations are variable. A moderate cover of weeds, grasses, or legumes protects planted trees from drying winds, accelerates soil formation, reduces erosion losses, and improves growing conditions by the addition of organic matter and nitrogen to the spoils. On the other hand, dense ground cover may compete with planted trees, and thus make necessary a more careful choice of species and the use of larger, better-balanced stock. In the case of coniferous stock periodic release cuttings may be needed during the first two seasons after planting.

On Experiment No. 6 (table 4) 16 percent of the mortality was due to competition of weeds and legumes, but on Experiment No. 7 no losses from this cause were observed. The former area is generally calcareous and has a rather dense cover of sweetclover and weeds. The latter is acid and practically devoid of natural vegetation. On most acid banks in the state weeds and grasses are generally beneficial to tree growth. They are rarely dense enough to offer serious competition except possibly on those banks which also have an overstory of black locust.

Areas with dense cover of weeds and grasses often attract rabbits, mice, and other rodents. Plantations on them may suffer severe damage from these animals.

Grading of Spoil Banks

Experiments to determine the effects of grading strip-mined lands on growth and survival of forest plantations have only recently been initiated. They are regional in scope, extending from eastern Ohio to Kansas, and were established in 1946 and 1947. Early survival and growth on experimental areas indicate trends but cannot be regarded as conclusive.

Results obtained from three grading experiments in Ohio 3 years after establishment indicate effects varying mainly with species planted, and with texture and consistency of spoil surfaces (table 6). On experimental areas No. 2 and No. 5 the spoils are shaly; the latter also has a considerable proportion of massive sandstone. Both have a relatively low percentage of soil of loose consistency. To date the results show no appreciable differences in survival and growth between graded and ungraded portions of these banks.

On Experimental Area No. 3, however, the data indicate definite detrimental effects of grading on survival and growth. The spoils on this area consist mainly of clay and limestone. Three degrees of grading were tested: (1) banks that were completely graded; (2) banks that were partially graded by "striking-off" the tops of ridges to a width of 15 to 20 feet; and (3) banks that were not graded (fig. 8 E, F &

G). After one year's observation it became evident that two different sites existed on the completely graded spoils. The first consisted of the "cut" portions, which were made up of material not moved in the grading operation and the second consisted of the "fill" portions, materials which originally were the upper halves of the ridges.

At the end of three growing seasons the average total height of black locust on the ungraded spoils was 10.6 feet. On the graded spoils the average height was 9.0 feet (fig. 8A). The differences in total height between trees planted on the "cut" and "fill" portions of the graded spoils—3 feet—are even more striking (fig. 8B). The average height on the "cut" portion of the graded spoils is nearly one foot less than that obtained on the tops of the partially graded spoils (fig. 8B and C) and more than 1½ feet less than the average height for the tops of the ungraded spoils. Tree heights on the slopes of the partially

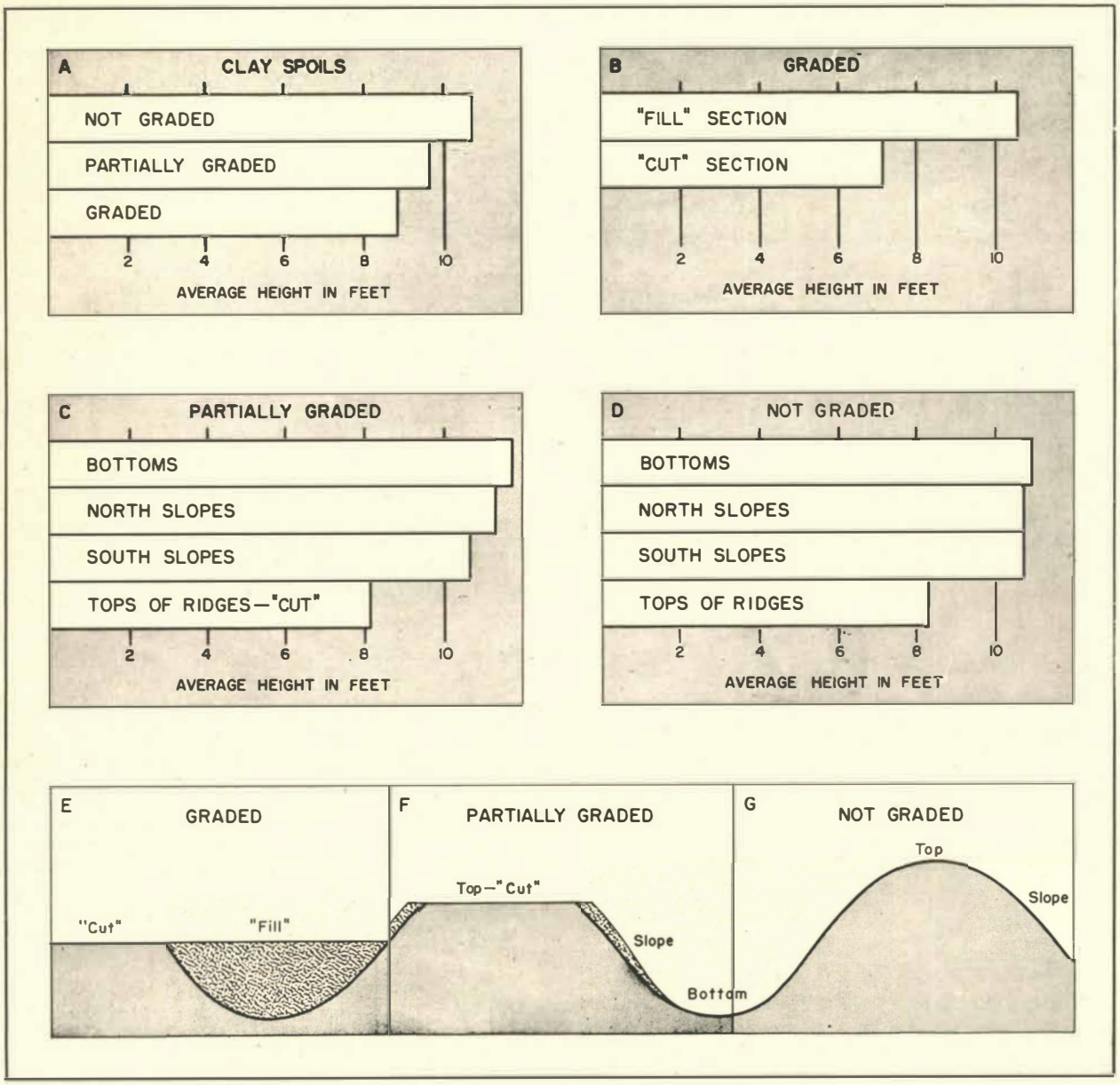

Figure 8.—(A, B, C, & D). Comparative height of black locust three years after planting on various site conditions existing on clay spoils graded, partially graded, and not graded. (E, F, & G). Schematic drawing of sites existing on the three areas.

Table 6.--Survival percent and height of trees planted on graded and ungraded spoils at end of third growing season

Experiment number and site description	Species and age class of planting stock	Survival: Graded	Survival: Not graded	Total height: Graded	Total height: Not graded
		Percent	Percent	Feet	Feet
2 Silty-shale loam--pH 5.6-6.9, 59% stone 41% soil, soil 40% clay, loose consistency	1-1 yellow poplar	64	64	0.7	0.8
	1-0 white ash	96	76	0.8	0.7
	3-0 red pine	73	81	0.9	1.1
3 Calcareous clay and limestone--pH 6.8-7.8, 44% stone 56% soil, soil 47% clay, friable to compact	1-1 yellow poplar	37	47	0.4	0.8
	2-0 white ash	92	93	1.4	1.8
	3-0 white pine	75	83	0.6	0.7
	1-0 black locust	100	95	9.0	10.6
5 Silty-shale clay-loam with sandstone--pH 6.0-7.0, 66% stone 34% soil, soil 34% clay, loose consistency	1-1 yellow poplar	81	73	0.8	0.9
	2-0 white ash	97	95	1.4	1.4
	3-0 white pine	89	89	0.9	1.0
	1-0 black locust	95	99	9.4	9.9

Table 7.--Planting time and survival percent on spoil banks by three planting methods

Method of planting	Survival: Exp. #6: 2-2 white pine	Survival: Exp. #7: 2-2 white pine	Survival: Exp. #7: 1-1 yellow poplar	Trees planted per 8-hour man-day 1/: Exp. #6: 2-2 white pine	Trees planted per 8-hour man-day 1/: Exp. #7: 2-2 white pine	Trees planted per 8-hour man-day 1/: Exp. #7: 1-1 yellow poplar
	Percent	Percent	Percent	Number	Number	Number
Bar-slit	83.0	98.0	91.5	650	513	560
Side-hole-mattock	89.5	99.5	83.5	560	408	560
Mattock and tamper	91.0	94.5	86.6	280	280	265

1/ Based on 50 minutes effective planting time per hour.

graded banks are about the same as on the slopes of the banks not graded.

These results, though still tentative, indicate that for clay spoils the degree of grading has an important effect on height growth of planted trees. The greater the degree of grading, the greater will be the reduction in growth of trees on these banks. There is also some evidence that the choice of species for planting on graded clay spoils is much more limited than that on the undisturbed. Only those species that are able to tolerate tight, impervious, water-logged soils are adapted to graded clay spoils.

The methods used in grading operations have an effect on the degree of compaction of the spoil surfaces. If banks could be graded without the use of such heavy equipment as bulldozers and carry-alls, adverse effects on plant growth would no doubt be somewhat lessened. Furthermore if grading work were done at the time of the year when spoils are relatively dry, such as late summer or early fall, the degree of compaction would be reduced to some extent.

Methods of Planting

The cost of establishing a forest cover on strip-mined lands varies considerably with site conditions and methods of planting. The two methods commonly employed, and generally the most costly, are: (1) the side-hole method using a grub hoe or mattock and (2) the center-hole method using a mattock and a tamper to pack the soil around the tree. A third method, known as the bar-slit method, is cheaper but to date has not been widely used in the state. Several companies in Ohio have used it for the planting of more than a million trees with satisfactory results and reduced costs. In Indiana it is used almost exclusively for the planting of stripped lands.

In 1946 two tests were initiated to compare results of planting by these three methods. One was located on a clay-limestone site (Experiment No. 6) and the other on a shaly loam spoil (Experiment No. 7). At the end of the first growing season, no appreciable differences in survival between the three methods were found (table 7). Time studies indicated the possibility of planting more than 650 trees per man-day by the bar-slit method on shaly sites, 560 trees by the side-hole method, and only 280 by the center-hole and tamper method. These results, substantiated by large-scale tests made elsewhere, indicate that planting on loose, shaly spoils by the bar-slit method will give satisfactory results at costs much lower than by the slower mattock methods now generally in use. The bar-slit method is not yet recommended for general use on spoils composed mainly of clay, nor for those spoils which contain considerable massive limestone and sandstone.

Planting Under Black Locust

Although the conversion of some black locust stands to more valuable species is recommended, the time of underplanting has been found to be very important. Observations on strip-mined lands throughout the Central States have shown that in 5 to 10 years a very dense undergrowth generally develops in black locust plantations. After this dense undergrowth becomes established underplanting becomes more expensive; because of their inability to compete with the surrounding herbaceous vegetation, the initial survival of some desirable species is poor.

An underplanting test on this kind of site in Jefferson County was made in the spring of 1946 (table 8). The overstory

Table 8.--Comparative first- and second-year survivals and second-year total heights of trees planted on barren spoil banks, and on spoil banks with a decadent black locust stand having a dense undergrowth

Species and age class of planting stock	Barren spoils			Black locust overstory with dense undergrowth		
	Survival		Average	Survival		Average
	First year	Second year	total height	First year	Second year	total height
	Percent	Percent	Feet	Percent	Percent	Feet
1 - 0 Yellow poplar	73	57	.50	62	9	.86
1 - 0 White ash	96	96	1.14	91	63	1.45
2 - 2 White pine	86	82	.41	28	9	.48
Average all species	85	78	.68	60	27	.93

consisted mainly of a decadent stand of black locust (table 9) about 10 years old and a fair stand of volunteer ash and elm. The understory was composed mainly of a very dense growth of briar and herbaceous vegetation. Three species were underplanted and for comparison, the same species were planted on an adjacent stripped area having no overhead cover. As shown in table 8 survival under the locust overstory was much lower than on the barren area, especially for white pine and yellow poplar. White ash appears to have been tolerant enough to survive fairly well under the dense cover which existed on the area; white pine and yellow poplar were definite failures. Although these tests are only preliminary they do give strong evidence of the need for careful selection of species for conversion planting. They also suggest that, if mixed plantings are desired, the underplanting should be made before dense ground vegetation develops under the locust stand. This is especially true for such desirable species as yellow poplar and black walnut. Current investigations include the study of mixed plantings of a variety of species with black locust, and the study of underplantings at an early date after the establishment of black locust. From the standpoint of cost and practicability mixed plantings appear to be more expedient than subsequent underplanting.

Table 9.--Number of trees per acre in the black locust overstory by diameter class and species

Diameter breast high (Inches)	Planted		Volunteer	
	Black locust		White ash	Red elm
	Living	Dead	Living	Living
0 - 1.5	567	8	42	92
1.6 - 2.5	185	133	8	100
2.6 - 3.5	133	166	8	8
3.6 - 4.5	42	158	0	0
4.6 - 5.5	17	116	0	0
5.6 - 6.5	0	42	0	0
6.6 - 7.5	0	42	0	0
Total	944	665	58	200

The two most important causes of mortality in these underplantings appear to be the heavy herbaceous cover and rabbit damage. Rabbits have damaged some of the trees during both growing seasons, and there is little chance that these trees will be able to survive in the heavy herbaceous cover which has closed over them.

A study of table 9 will also disclose a surprising number of trees of other species developing naturally in the black locust stand. If underplanting of stands of this kind is contemplated, a careful inventory of the stand should first be made to determine the number of trees of desirable species already in the stand. It may be possible that many of these areas do not need underplanting.

Seasons For Planting

Spring planting has generally proved to be superior to fall planting in the Central States. A very limited number of spring- versus fall-planting tests have been made on strip-mined lands. One test, using shortleaf and pitch pine seedlings, was made in the fall of 1937 and the spring of 1938 on banks in Perry County (1). The survival 7 years later was 38.6 percent for the fall-planted stock and 95 percent for the spring-planted stock. Average heights were 8.6 and 11.0 feet, respectively. The losses sustained by the fall-planted stock were due chiefly to frost-heaving and winter-killing.

In order to distribute the work-load more evenly throughout the year, some companies and public agencies may wish to do some fall planting. It should be attempted only on a small scale for a few years and should be limited to loose, shaly spoils, or to spoils having dense ground cover. Well-balanced stock is especially desirable for fall planting.

Direct Seeding Studies

Because of the lack of competing vegetation and the absence of a layer of duff and litter bare mineral soil often presents favorable conditions for germination of tree seed. Wherever mineral soil is exposed after fires or land-clearing operations light-seeded hardwoods and pines frequently establish themselves. Since similar conditions exist on many spoil banks the possi-

Table 10. — Germination and first-year survival percentages from direct seeding tests on spoil banks by species and site

Species	Germination - Proportion of total number of seeds that germinated				Survival - Proportion of seedlings living at end of first summer				Proportion of seed spots with one or more seedlings at end of first summer			
	Limestone sites		Acid-shale sites		Limestone sites		Acid-shale sites		Limestone sites		Acid-shale sites	
	North slopes	South slopes	North slopes	South slopes	North slopes	South slopes	North slopes	South slopes	North slopes	South slopes	North slopes	South slopes
	Per Cent											
White ash	0	0	0	0	0	0	0	0	0	0	0	0
Black locust	17	15	4	3	39	78	30	23	20	22	1	.7
Jack pine	16	21	8	6	55	70	22	50	22	40	1	1.5
Pitch pine	22	13	13	4	57	60	22	49	30	22	2	2.5
Black cherry	.5	0	0	0	0	0	0	0	0	0	0	0
Shortleaf pine	12	6	4	4	40	30	8	16	18	10	.3	.4
Loblolly pine	2	3	2	3	70	100	40	30	8	8	.3	.4
Eastern red cedar	0	0	0	0	0	0	0	0	0	0	0	0
Sycamore	2	0	0	.3	100	0	0	0	17	0	0	0
Bur oak	50	48	66	66	100	100	100	88	50	48	66	58
Black walnut	33	43	11	26	100	100	100	100	33	43	12	39

bility of establishing forest stands on these areas by direct seeding should not be overlooked.

In the spring of 1947 two direct seeding tests were made on each of two spoil types in Ohio. One was on a limestone-clay site and the other on an acid silty-shale site. Six direct-seeding plots, three on south-facing slopes and three on north-facing slopes, were established on each of the four areas. Eleven species were seeded in eleven separate rows on each plot. Seed was placed in 10 spots in each row. Three seeds of black locust were placed in each spot seeded to this species; in spots seeded to white ash, jack pine, pitch pine, black cherry, shortleaf pine, loblolly pine, eastern red cedar, and sycamore, five seeds were placed. Only one seed of bur oak and black walnut was placed in each spot seeded to these species.

Cutting tests showed good viability for all seed used except eastern red cedar. The bur oak and black walnut seed was stratified during the winter prior to the seeding, and subsequently all seeds which floated in water were discarded. Black locust seed was soaked in hot water before planting. To provide a medium for mycorrhizal development a handful of soil from a pine plantation was placed in each spot seeded to conifers. Except for a few species the first-year's results do not indicate that direct seeding is a promising method for revegetating strip-mined lands (table 10).

The first-year results of the foregoing direct seeding tests are summarized as follows:

1. Direct seeding failed to establish an acceptable stand inasmuch as seedlings survived on only 14 percent of the seed spots.
2. Failure to establish a stand was attributed entirely to poor germination, or to losses before germination; only 7 per cent of the seed germinated.
3. Germination was almost twice as great on the limestone-clay spoils as on the acid-shale spoils. Survival of seedlings that germinated was more than 8 percent greater on limestone-clay spoils than on the acid-shale spoils.
4. Soil movement caused by water and wind action accounted for considerable losses for such light-seeded species as pine, sycamore, and locust. Much of this seed was uncovered and washed away or deeply buried despite precautions taken to prevent losses from this cause.
5. Poor germination of black locust and black cherry was in part due to improper treatment of the seed before planting.
6. The survival of bur oak and black walnut was greater than for the other species tested. If two seeds of these species had been placed in each spot, a satisfactory stand might have resulted.
7. The germination percents were nearly the same for both north and south slopes.
8. These results should not be regarded as conclusive. Untested procedures may yield more encouraging results. These include the use of pelletized seed, newly discovered methods of seed treatment, repellents to reduce losses from rodents, and techniques to control erosion.

FOREST PLANTING RECOMMENDATIONS

General recommendations for planting on strip-mined lands in the Central States have already been published (4). Among other items these include (1) tentative planting guides based on the classification of spoil banks by acidity and texture classes; (2) precautions to be taken in planting areas where serious toxic conditions prevail or where the danger of landslides is great; (3) special rules for the planting of red cedar in proximity to apple orchards; and (4) specific recommenda-

tions on the choice of species, seasons for planting, spacing, advantages of black locust-hardwood mixtures, suggested arrangements for mixed planting, care of stock, methods of planting, care of plantations, direct seeding, and the use of exotic species. The following suggestions supplement those general recommendations and are particularly adapted to conditions on spoil banks in Ohio.

Planting Surveys

Before making plans to plant a strip-mined area it should be carefully examined to determine its size and condition. A suggested outline for recording data helpful in planting-site evaluation and a sample map for supplementary information are given in Appendix I (page 26).

Spacing

For general forest planting practice on spoil banks a spacing of 7- by 7-feet is recommended. Plantings for erosion control, landscape beautification, or the production of Christmas trees can be made at a closer spacing. In the regular planting operation no attempt should be made to follow the prescribed spacing rigidly. Avoid spots composed entirely of stones, and do not plant in depressions that are filled with water during most of the year. The crests of ridges should not be planted, even if this practice results in some spacing irregularity.

Mixed Planting

Mixed plantings, especially of black locust and other hardwoods, are desirable. Insofar as practicable, the species to be planted on a given site should be adapted to it. The bottoms and lower slopes of an area, for example, may be suitable for yellow poplar, chestnut oak, and black walnut. On these sites a mixture of 50 percent black locust in combination with all of these species is recommended. Because yellow poplar and black walnut are not adapted to dry exposed sites, the upper slopes in this case should only be planted to black locust and chestnut oak. On slopes subject to severe gullying the proportion of black locust should be increased.

Species Recommended For Planting

The following species are suitable for planting on certain types of spoils in Ohio. Although these recommendations should be regarded as tentative, they are based on general observations and available experimental data and represent what is considered to be acceptable practice.

1. Green ash **(Fraxinus lanceolata).** Adapted to all plantable spoil banks in the state, but better development will be obtained on moist sites. On barren spoils should be planted in equal proportions with black locust or should be mixed with other hardwoods and black locust. Can be underplanted in black locust stands if the ground cover is not too dense. Subject to severe injury by rabbits.

2. White ash **(Fraxinus americana).** A more promising species than green ash. Adapted to loamy and clayey spoils, especially those banks with a high proportion of soil. Is especially tolerant of the compact soil conditions existing where clay spoils are graded. On barren spoils plant in 50-50 mixture with black locust, or with 50 percent black locust and the remaining 50 percent a mixture of white ash with other hardwoods. Restrict planting generally to bottoms and lower slopes. Can be underplanted in black locust stands if ground cover is not high enough to overtop seedlings. Also adaptable to spoils with dense low ground cover. Subject to severe damage from rabbits.

3. Eastern red cedar **(Juniperus virginiana).** Limit planting to calcareous spoils. Grows very slowly on acid banks. Do not plant within 1 mile of apple or pear orchards. Can be planted in pure stands or in mixture with pine or hardwoods. One of the few conifers that can be underplanted in black locust stands.

4. Cottonwood **(Populus deltoides).** Adapted to all plantable spoil banks in the state, but better growth and development are attained on loamy and clayey sites. Can be planted in pure stands or in mixture with black locust. Should not be used in underplanting.

5. Black cherry **(Prunus serotina).** Adapted to calcareous, loamy, and clayey banks with a high proportion of soil. Plant in mixture with black locust and other hardwoods. Can be used in underplanting.

6. Red elm **(Ulmus fulva).** Well adapted to loamy and clayey spoils, especially the calcareous banks located in Belmont, Harrison and Jefferson Counties. Can be planted in pure stands or in mixture with black locust and other hardwoods. Can be used in underplanting.

7. Rock elm **(Ulmus racemosa).** Probably a good species for planting on sites similar to those recommended for red elm.

8. Red or sweet gum **(Liquidambar styraciflua).** Adapted to clay spoils and to loamy and sandy spoils having a reasonably high percentage of soil. In Ohio limit planting generally to banks south of U. S. Highway 40. Plant in mixture with black locust and other hardwoods. Do not use in underplanting. Is especially susceptible to damage by rabbits.

9. Black locust **(Robinia pseudoacacia).** Will survive on all plantable spoil banks in the state, but growth and development varies considerably with site. Subject to very severe damage by the locust borer on most sites, but is valuable as a nurse crop, for soil improvement, and for erosion control. May not develop merchantable products on most plantings, but is recommended for planting with other hardwoods to accelerate their growth.

10. Hard or sugar maple **(Acer saccharum).** Site requirements on spoil banks not too well known. A few good stands of volunteers have been observed on calcareous clay banks in Harrison and Jefferson Counties. Should be planted in mixture with black locust or with black locust and other hardwoods. Can be used in underplanting.

11. Silver or soft maple **(Acer saccharinum).** Adapted to all plantable spoils having a high proportion of soil. Should be planted in mixture with black locust, or with black locust and other hardwoods, or in pure stands. Grows rather slowly when used in underplanting.

12. Bur oak **(Quercus macrocarpa).** Well adapted to most plantable spoil banks in th state, although better growth is obtained on moist sites. Should be planted (or seeded) in mixture with black locust or with black locust and other hardwoods. Grows rather slowly under dense overstory.

13. Chestnut oak **(Quercus montana).** Adapted to the drier upper slopes and ridgetops of spoil banks, but will grow best on the moister, better-drained sites. Can be planted in mixture with black locust or with black locust and other hardwoods. Can be used in underplanting.

14. Red oak **(Quercus borealis).** Same as for chestnut oak, except that red oak is not so well adapted to the drier sites.

15. White oak **(Quercus alba).** Adapted to the loamy and clayey spoils with high proportion of soil, and with a pH range from 5.5 to 8.0. Plant only on bottoms and lower slopes having some volunteer growth of other hardwoods, or in mixture with black locust or with black locust and other hardwoods. Can be used in underplanting. A slow-growing species.

16. Jack pine **(Pinus Banksiana).** Well adapted to the drier ridgetops and upper slopes as well as to the moister, better-drained lower slopes on all sandy and loamy spoils and on clay spoils having a high proportion of stone. Plant in pure stands or in group-mixtures with other conifers. Do not use in underplanting.

17. Pitch pine **(Pinus rigida).** Same site requirements and recommendations as for jack pine.

18. Red pine **(Pinus resinosa).** Same as for jack pine.

19. Shortleaf pine **(Pinus echinata).** In Ohio limit plantings generally to banks located south of U. S. Highway No. 40. Do not plant on calcareous spoils. Otherwise site requirements and recommendations are the same as for jack pine.

20. Virginia pine **(Pinus virginiana).** Same as for jack pine.

21. White pine **(Pinus Strobus).** Limit plantings to loamy spoils and to sandy spoils having a high percentage of soil. Plant in pure stands or in group-mixtures with other conifers. Can be planted under a thin overstory of black locust, if the ground cover is sparse and does not overtop the seedlings.

22. Tulip poplar, tulip tree or yellow poplar **(Liriodendron tulipifera).** Adapted to loamy and clayey banks in protected locations, preferably where pH ranges between 5.5 and 8.0. Should be planted in bottoms and on lower slopes of areas already with some cover of volunteers, or in mixture with black locust or black locust and other hardwoods. Can be underplanted in black locust stands providing ground cover does not overtop planted seedlings.

23. Sycamore or plane tree **(Platanus occidentalis).** Adapted to moist sites. Can be planted in pure stands or in mixture with black locust or black locust and other hardwoods. Should not be used in underplanting.

24. Black walnut **(Juglans nigra).** Same site requirements and recommendations as for tulip poplar.

25. Exotic species. A few European and Asiatic species seem to be suitable for planting on strip-mined lands, but very few of their site requirements are known. Scotch pine and the European and Japanese larches may develop good stands on sites similar to those recommended for the native pines.

SUPPLEMENTARY PUBLICATIONS

During the period 1945 to 1947 when the reconnaissance of strip-mined lands in the state was made, much detailed data were collected. These data include descriptions of physical characteristics of specific areas, descriptions of strata overlying the coal seams mined, chemical analyses of high-wall strata and spoil surfaces, and reconnaissance maps showing the location of banks, spoil types, and outcrop lines of principal coal seams. They provide not only detailed information on existing strip-mined lands but describe conditions that may be expected in future operations for a given locality and coal seam. Some of this information may be of use to individuals, companies, and public agencies concerned with the development of these lands. Separate publications containing some of the foregoing data are planned for the counties in the state where strip-mining activity is concentrated.

APPENDIX I

Page

1. Planting-site evaluation form 27

2. Planting survey map 29

3. Instructions for using the planting-site evaluation form 30

PLANTING-SITE EVALUATION FORM

County Carroll Township Rose, T.12N.R.4W Section 22

Area No. 1 Acreage to be planted 70

Name and address of owner George Mackey, Carrollton, Ohio

Year stripped 1946 Coal vein mined #6 Method of stripping Shovel

Will future stripping operations result in placement of more spoil material on proposed planting area? No

Spoil Acidity

Sample pH determinations: 5.8 - 6.5 - 6.5 - 6.0 - 6.8 - 4.5 - 3.5 - 4.0 - 3.5 - 3.0 - 5.5 - 6.0 - 6.5 - 6.0 - 4.5

Estimated percent of total area with pH less than 4.0 10 %; with pH between 4.0 and 5.0 20 %; between 5.0 and 6.9 70 %; pH of 7.0 or above none %.

Acidity class (underline one): Toxic, marginal, acid, calcareous, mixed.

Spoil Texture and Consistency

Percent stone 60 % (of which 40 % is shale, 20 % sandstone, — % limestone, — % glacial). Percent soil 40 %.

Is spoil material sandy, loamy, or clayey? (underline one).

Consistency (underline one): Very loose, loose, friable, compact, very compact. Is area plantable with planting bar or mattock? (underline one).

Spoil Type 3-B.

Spoil Stability and Topography

Proportion of area with steep outside slopes 20 %, low ridges 80 %, high ridges — %, leveled — %, partially leveled — %.

Is loose material sliding down slopes? No. Is there danger of entire mass slipping downward? Yes - In Area 1-B.

Density of Ground Cover (underline one): Dense, medium density, sparse, barren.

Predominating species of ground cover Wild lettuce, some goldenrod.

(over)

Forest Cover

Species	red elm	fire cherry	
Estimated No. of trees per acre	5	10	

Erosion (check one): Slight ✓ Moderate _____ Severe _____

Access Roads: Adequate ✓. (If inadequate, show needed road locations on map).

Planting Recommendations: Year to plant 1950.

Species for planting: (Indicate also spacing and percent mixture)

On outside slopes 75% B. Locust, 25% Y.P. (6'x6')

On upper slopes and tops of ridges 50% B.L., 50% C.O. (7'x7')

On lower slopes and bottoms 50% B.L., 50% Y.P. (7'x7')

On leveled areas —

On other areas (specify) —

Planting Stock Needed

Species	B.L.	Y.P.	C.O.		
Age class	1-0	1-0	1-0		
Number of trees	40 m	15 m	15 m		

Remarks: Area 1-B should not be planted in 1950- danger of slipping. Do not plant this area and field below until 1954.

John Doe
Examiner

7-15-48
Date

(Note: The foreman in charge of planting the area should be given a copy of this report and the map. He should indicate in red pencil any deviations from the original plan).

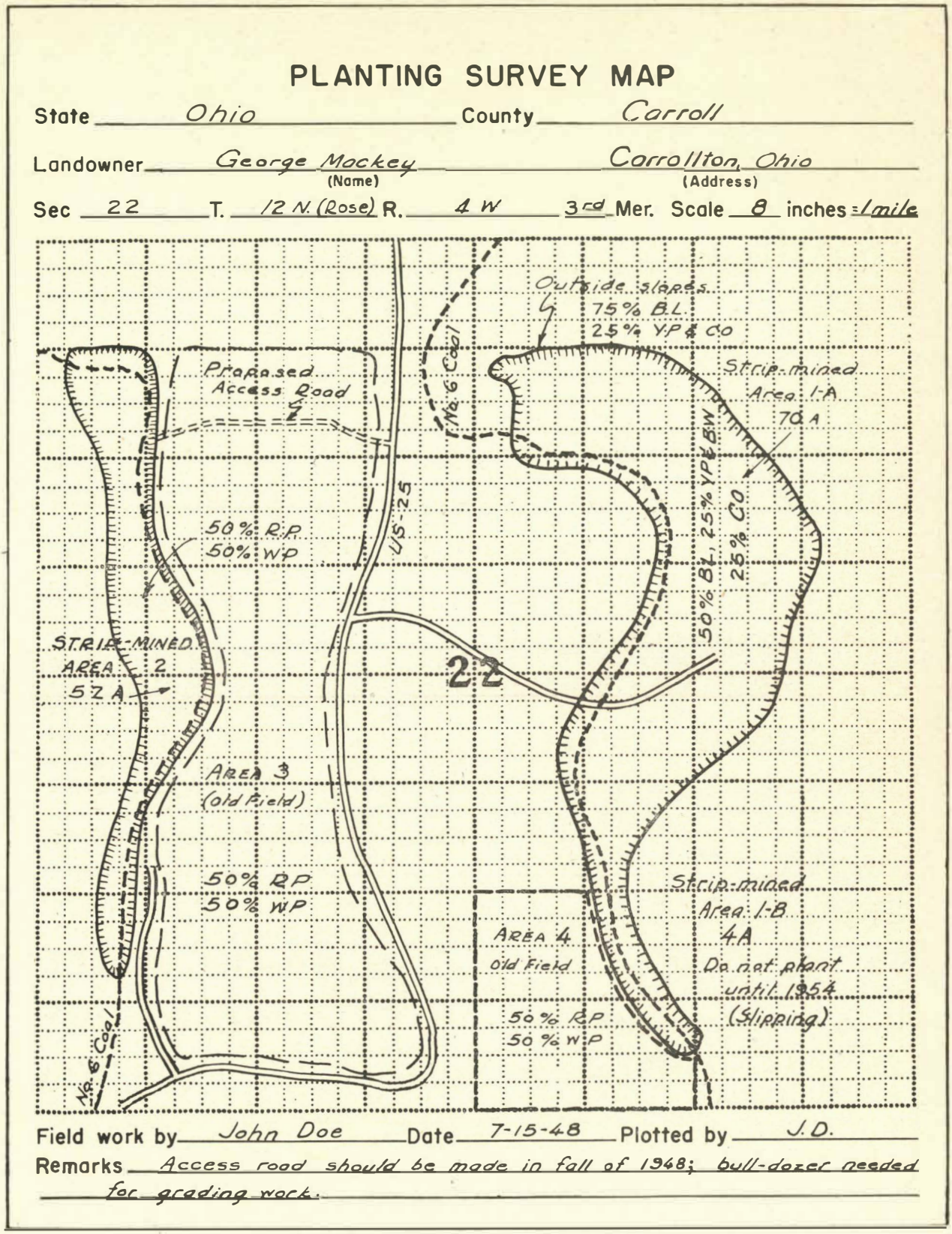

Figure 9.—Sample planting survey map on a reduced scale.

Instructions For Using Planting-Site Evaluation Form

Some of the items on the planting-site evaluation form are self-explanatory. The following captions may need clarification:

1. **Area No.** Within a given section each stripped area, and undisturbed areas to be planted, should be designated and given a number. Information for only one area should be recorded on a single form. Areas with minor site differences, or locations recommended for special treatments can be designated as A, B, and C. Thus area 1 has been divided into 1A and 1B.
2. **Will future stripping operations result in placement of more spoil material on proposed planting area?** Planting plans should be coordinated with stripping operations, so that no plantations are established which may be destroyed by further mining operations. Some strip-mined areas have even been restripped for underlying coal and clay.
3. **Spoil acidity.** Sufficient pH readings should be taken to determine spoil type and to estimate the percentage of total area plantable and nonplantable. These determinations should be made to a depth of at least 12 inches, because often the surface material does not have the same acidity as the material directly beneath. The number of samples needed will vary according to the uniformity of acidity conditions. For the limestone-clay spoils resulting from the mining of No. 8 Pittsburgh coal, for example, only a few samples need be taken. On the other hand spoils resulting from mining of the No. 4a, 5, or 6 coal seams may need many determinations. In the latter cases it may be desirable to take samples in strips about 300 feet apart at regular intervals across the area.
4. **Spoil texture and consistency.** The percentage of soil may be a little difficult to determine until the examiner has become experienced. Ordinarily ocular estimates will suffice, but judgement should be checked by specific determinations. To make these fill a can (about 1 quart capacity) with an air-dry sample of spoil material taken from a spot typical of those to be planted. Pack the material in the can gently, so that no stones are broken in the packing operation. Then empty the can and place the material in a mortar or on any hard surface. Using a pestle or stick with a rounded edge, pulverize the material gently and break up all soil aggregates, but be careful not to break up individual stone particles. Place all the material on a No. 10 mesh screen and sift out the soil-sized particles. Replace the soil in the can, pack gently, and measure the distance from the top of the soil to the top of the can. If for example, this distance is 3 inches and the total depth of the can is 6 inches, the sample is about 50 percent soil.

APPENDIX II

Description and chemical[1] analyses of typical sections of overburden for the principal coal seams strip-mined in Ohio.

Table No.	Coal Seam	County
11	No. 1 Sharon	Jackson
12	No. 4 Brookville	Wayne
13	No. 4 Brookville	Stark
14	No. 4a Clarion	Vinton
15	No. 4a Clarion	Jackson
16	No. 5 Lower Kittanning	Jackson
17	No. 5 Lower Kittanning	Mahoning
18	No. 5 Lower Kittanning	Mahoning
19	No. 5 Lower Kittanning	Stark
20	No. 5 Lower Kittanning	Tuscarawas
21	No. 6 Middle Kittanning	Athens
22	No. 6 Middle Kittanning	Mahoning
23	No. 6 Middle Kittanning	Carroll
24	No. 6 Middle Kittanning	Stark
25	No. 7 Upper Freeport	Athens
26	No. 7 Upper Freeport	Athens
27	No. 7 Upper Freeport	Columbiana
28	Mahoning	Columbiana
29	Mahoning	Columbiana
30	No. 8 Pittsburgh	Athens
31	No. 8 Pittsburgh	Harrison
32	No. 8 Pittsburgh	Jefferson
33	No. 9 Sewickley	Harrison
34	No. 9 Sewickley	Belmont

[1]Credit is due George R. Blake, Research Fellow, Department of Agronomy, Ohio State University for the chemical analyses reported in the tables which follow.

Table 11.—**Description and chemical analyses of strata over the No. 1 Sharon coal seam, Section 15, Liberty Township, Jackson County, Ohio.**

Description of strata (Top to bottom)	Thickness (Feet)	Acidity (pH)	Available nutrients	
			Phosphorus	Potash
Soil—gray loam, acidic	1	5.3	Low	Low
Sandstone—brown, acidic, thin - bedded, hard, somewhat ferruginous and mixed with loose sand	6	5.9	Medium	Low
Shale—gray-blue, calcareous, thick - bedded, silty (sometimes sandy), very hard, bony, and only slightly ferruginous	20	7.2	Medium	Low
Clay—gray-black, acidic; near top of this seam is a narrow (1/2") band of calcareous sandstone; in the middle is a 2" band of coal	1	6.4	High	Low
Coal—No. 1, Sharon				

Table 12.—**Description and chemical analyses of strata over the No. 4 Brookville coal seam, Section 18, Paint Township, Wayne County, Ohio.**

Description of strata (Top to bottom)	Thickness (Feet)	Acidity (pH)	Available nutrients	
			Phosphorus	Potash
Soil—gray silty clay loam, acidic, pebbly	0.5	5.5	High	Low
Subsoil—glacial silty clay, acidic, mixed with rounded igneous rocks	1	5.3	Low	Low
Glacial till—mixture of sand, clay, sandstone, and igneous rocks; calcareous	24	7.5	High	Low
Shale—gray, very hard, thin-bedded, mixed with highly acidic ferruginous ores	12	7.2	Low	Low
Coal—No. 4, Brookville				

Table 13.—**Description and chemical analyses of strata over the No. 4 Brookville coal seam, Section 8, Pike Township, Stark County, Ohio**

Description of strata (Top to bottom)	Thickness (Feet)	Acidity (pH)	Available nutrients	
			Phosphorus	Potash
Soil—gray, silty clay loam, acidic	0.5	4.3	Low	Low
Shale—gray, acidic, thin-bedded, silty to fine sandy in texture, mixed with mottled orange concretions	10	4.6	Medium	Low
Sandstone—gray, acidic, massive	4	5.4	Medium	Low
Shale—acidic, thick-bedded, sandy to silty, ferruginous	1 to 5	5.0	Medium	Low
Shale—gray, acidic, thin-bedded, silty, fossiliferous, mixed with numerous small calcareous nodules	6	5.6	Medium	Low
Shale—clayey, highly acidic, soft, rotten, ten, carbonaceous	1	2.8	Low	Medium
Limestone—Putnam Hill, gray, massive	3	——	Low	Low
Coal—No. 4, Brookville				

Table 14.—**Description and chemical analyses of strata over the No. 4a Clarion coal seam, Section 26, Elk Township, Vinton County, Ohio**

Description of strata (Top to bottom)	Thickness (Feet)	Acidity (pH)	Available nutrients	
			Phosphorus	Potash
Soil—stoney sandy loam, acidic	0.5	4.6	Low	Low
Shale—sandy, acidic, ferruginous, thin-bedded, mixed with sand or thin - bedded sandstone, gray to brown	6	4.0	Medium	Low
Sandstone—brown, acidic, massive and fragmental, ferruginous, slightly micaceous	5	5.1	Low	Low
Shale—clayey, gray to black, acidic, nut-like structure, carbonaceous, sooty	6	4.0	Low	Medium
Sandstone—gray, acidic, massive, in places very ferruginous	——	4.7	Low	Low
Shale—gray, clayey, hard, fossiliferous, with very hard, steel - gray stones	12	6.9	High	Low
Shale—clayey, highly acidic, ferruginous. carbonaceous	1	2.9	Low	High
Coal—No. 4a, Clarion				

Table 15.—**Description and chemical analyses of strata over the No. 4a Clarion coal seam, Section 31, Madison Township, Jackson County, Ohio**

Description of strata (Top to bottom)	Thickness (Feet)	Acidity (pH)	Available nutrients	
			Phosphorus	Potash
Soil—gray silt loam, acidic	0.5	5.7	Low	Low
Subsoil—sandy clay, acidic, mixed with fragments of sandstone	2	5.1	Low	Medium
Sandstone—brown, hard, massive, acidic, mixed with iron concretions	16	5.7	High	Low
Shale—gray, clayey, acidic, soft, blocky structure	8	6.4	Low	Low
Limestone—hard, gray, ferruginous, somewhat massive	1	——	Low	Low
Shale—gray, blocky, hard, clayey	2	7.0	Low	Medium
Coal—No. 4a, Clarion				

Table 16.—**Description and chemical analyses of strata over the No. 5 Lower Kittanning coal seam, Section 31, Madison Township, Jackson County, Ohio**

Description of strata (Top to bottom)	Thickness (Feet)	Acidity (pH)	Available nutrients	
			Phosphorus	Potash
Soil—gray sandy loam, acidic	1	5.2	Low	Low
Subsoil—brown sand, acidic	3	4.8	Low	Low
Sandstone—brown, acidic, very soft, massive	6	4.6	Low	Low
Clay—gray with brown mottling, plastic, ferruginous, acidic	4	4.2	Low	Low
Shale—silty and clayey, thin-bedded, acidic, somewhat ferruginous; lower portions slightly fossiliferous	8	4.3	High	Low
Shale—silty, gray, acidic, hard, fossiliferous; slightly carbonaceous	1	3.9	High	Low
Coal—No. 5, Lower Kittanning				

Table 17.—**Description and chemical analyses of strata over the No. 5 Lower Kittanning coal seam, Section 12, Beaver Township, Mahoning County, Ohio**

Description of strata (Top to bottom)	Thickness (Feet)	Acidity (pH)	Available nutrients	
			Phosphorus	Potash
Soil—gray loam, acidic	0.5	4.2	Low	Low
Glacial till—yellow - brown sandy clay, acidic and mixed with rounded igneous rocks	4	4.7	Low	Low
Soot streak—carbonaceous, shaly, with some clay particles (possibly outcrop of the No. 6 Middle Kittanning coal seam)	3	5.0	Low	Low
Shale—gray. soft, thin-bedded, clayey, and acidic	30	3.0	Low	Low
Shale—hard, thin-bedded, orange mottling, acidic, fossiliferous, with concretions and red kidney ores	6	3.9	Medium	Low

Table 18.—**Description and chemical analyses of strata over the No. 5 Lower Kittanning coal seam, Section 29, Smith Township, Mahoning County, Ohio**

Description of strata (Top to bottom)	Thickness (Feet)	Acidity (pH)	Available nutrients	
			Phosphorus	Potash
Soil—brown to yellow - brown silt loam, acidic	0.5	5.2	Medium	Low
Clay—reddish, shaly, acidic, ferruginous	9	4.2	Medium	Low
Shale—reddish gray, mixed with red kidney ores	16	7.4	Medium	Low
Shale—gray, clayey, mixed with nodules of calcareous rock	3	8.1	Low	Low
Coal—No. 5, Lower Kittanning				

Table 19.—**Description and chemical analyses of strata over the No. 5 Lower Kittanning coal seam, Section 23, Canton Township, Stark County, Ohio**

Description of strata (Top to bottom)	Thickness (Feet)	Acidity (pH)	Available nutrients	
			Phosphorus	Potash
Soil—gray brown sandy loam, acidic	1	4.4	High	Low
Sandstone—gray, massive, acidic	2	4.4	Medium	Low
Clay—yellowish orange, ferruginous, plastic, acidic	5	3.9	Medium	Low
Coal—No. 5a, Strasburg, sooty	1	3.4	High	Low
Shale—gray-black, highly acidic, soft, thin-bedded, carbonaceous, mixed with some nodular limestone and ferruginous concretions	8	3.2	Medium	Medium
Shale—clayey, highly acidic, soft, carbonaceous, mixed with an 8" band of hard ferruginous rock	2	3.2	Low	High

Table 20.—**Description and chemical analyses of strata over the No. 5 Lower Kittanning coal seam, Section 13, Wayne Township, Tuscarawas County, Ohio**[1]

Description of strata (Top to bottom)	Thickness (Feet)	Acidity (pH)	Available nutrients	
			Phosphorus	Potash
Soil—a brown loam, acidic	0.5	6.6	High	Low
Subsoil—reddish-yellow sandy loam, intermixed with sandstone fragments	5	5.8	Low	Low
Sandstone—fragmental, intermixed with reddish-yellow sand, slightly ferruginous	11	4.9	Low	Low
Shale—grayish black, mottled red, carbonaceous, thin-bedded	26	6.6	High	Medium
Shale—grayish black with red mottling, carbonaceous, intermixed with red kidney ores, concretions and some marcasite, acidic	11	7.0	High	High

[1]Chemical and mechanical analyses of near-by spoils are as follows:

Depth of sample	Acidity (pH)	Available nutrients		Percent stone	Soil fraction		
		Phosphorus	Potash		Sand	Silt	Clay
Inches					— —	Percent	— —
0-6	3.8	Medium	Low	66	27.6	34.6	37.8
6-12	3.4	High	Low	78	——	——	——
12-18	4.1	High	Low	88	——	——	——

Table 21.—**Description and chemical analyses of strata over the No. 6 Middle Kittanning coal seam, Section 29, York Township, Athens County, Ohio**

Description of strata (Top to bottom)	Thickness (Feet)	Acidity (pH)	Available nutrients	
			Phosphorus	Potash
Soil—gray silt-loam, acidic	0.5	5.3	Low	Low
Clay—gray, mixed with yellow mottled sandy clay, blocky structure, acidic	12	5.7	Medium	Low
Shale—gray to black, acidic, clayey, and thin-bedded	1	6.1	Low	Low
Coal—upper band of No. 6, shaly and of poor quality; not recovered in stripping operation	1	5.0	Medium	Low
Shale—gray to black, acidic; thick-bedded and partly ferruginous	2	4.5	Low	Low
Coal—No. 6, Middle Kittanning				

Table 22.—**Description and chemical analyses of strata over the No. 6 Middle Kittanning coal seam, Section 14, Beaver Township, Mahoning County, Ohio**

Description of strata (Top to bottom)	Thickness (Feet)	Acidity (pH)	Available nutrients	
			Phosphorus	Potash
Soil—gray silt loam	0.5	4.3	Medium	Low
Glacial till—sandy clay, mixed with rounded igneous rocks	12	5.2	Medium	Low
Sandstone—gray to brown, massive, coarse	6	6.1	High	Medium
Shale—gray to black, carbonaceous, thin-bedded, clayey; medium hardness	12	4.2	Medium	Low
Coal—upper band No. 6	1	——	——	——
Shale—gray-black, clayey	3	5.5	Medium	Low
Coal—No. 6, Middle Kittanning				

Table 23.—**Description and chemical analyses of strata over the No. 6 Middle Kittanning coal seam, Section 33, Rose Township, Carroll County, Ohio[1]**

Description of strata (Top to bottom)	Thickness (Feet)	Acidity (pH)	Available nutrients	
			Phosphorus	Potash
Soil—dark brown loam	0.5	5.3	Medium	Low
Subsoil—light brown silt loam	1	5.3	Low	Low
Shale—silty, mixed with sandy shale easily broken down to sand with fingers	6	6.4	Low	Low
Shale—thin-bedded, silty, with small amount of sandstone	19	6.8	High	Low
Coal—No. 6, Middle Kittanning				

[1]Analysis of near-by spoils is as follows:

Depth of sample	Acidity (pH)	Available nutrients		Percent stone	Soil fraction		
		Phosphorus	Potash		Sand	Silt	Clay
Inches					— —	Percent	— —
0-6	4.3	Medium	Low	51	16.6	45.4	38.0
6-12	4.0	Medium	Low	59	——	——	——
12-18	3.7	Low	Low	63	——	——	——

Table 24.—**Description and chemical analyses of strata over the No. 6 Middle Kittanning coal seam, Section 28, Osnaburg Township, Stark County, Ohio**

Description of strata (Top to bottom)	Thickness (Feet)	Acidity (pH)	Available nutrients	
			Phosphorus	Potash
Soil—gray silt loam	1	5.1	Low	Low
Subsoil—generally a silty thin - bedded shale, with little soil	3	5.1	Low	Low
Shale—gray-brown, silty, hard, thin - bedded, acidic; with some geodes and iron concretions	18	4.6	Low	Low
Shale—gray, clayey, hard, and flaky; thin and thick-bedded, ferruginous	12	5.9	Medium	Low
Shale—blue-gray to black; hard, thin-bedded and slaty; mixed with many acidic concretions	12	6.5	Medium	Low
Clay—a dark gray "Gob", highly acidic, with concretions	1	2.6	Medium	Low
Coal—No. 6, Middle Kittanning				

Table 25.—**Description and chemical analyses of strata over the No. 7 Upper Freeport coal seam, Section 2, York Township, Athens County, Ohio**

Description of strata (Top to bottom)	Thickness (Feet)	Acidity (pH)	Available nutrients	
			Phosphorus	Potash
Soil—gray to reddish-brown silt loam	1 to 2	4.7	Low	Low
Clay—nut-like structure; upper half reddish, lower half yellow-brown	3	4.3	Low	Low
Sandstone—brown to gray, acidic, rather soft, coarse, and micaceous; upper half thin-bedded and fragmental, lower half massive	26	6.1	Low	Low
Shale—gray to black, carbonaceous, flaky, fissile, soft, and clayey; thin-bedded but very compact and hard. Highly acidic	5	3.0	Medium	Low
Coal—No. 7, Upper Freeport				

Table 26.—**Description and chemical analyses of strata over the No. 7 Upper Freeport coal seam, Section 6, York Township, Athens County, Ohio**

Description of strata (Top to bottom)	Thickness (Feet)	Acidity (pH)	Available nutrients	
			Phosphorus	Potash
Soil—brown loamy sand; ("c" horizon only; "a" and "b" horizons absent)	6	4.5	Low	Low
Shale—silty, gray - green; almost coarse enough to be sandy; thick-bedded, mixed with red ferruginous fragments of sandstone. Lower half changing to yellow, thin-bedded sandstone	8	5.1	Low	Low
Shale—gray, thick - bedded, hard massive and silty	10	7.0	High	Low

Table 27.—**Description and chemical analyses of strata overlying the No. 7 Upper Freeport coal seam, Section 15, Elk Run Township, Columbiana County, Ohio[1]**

Description of strata (Top to bottom)	Thickness (Feet)	Acidity (pH)	Available nutrients	
			Phosphorus	Potash
Soil—Wooster loam, with glacial till	½	6.3	Medium	Low
Subsoil—brown sandy loam, with some shale and well-rounded stones (glacial)	1	5.2	Medium	Low
Outcrop—Mahoning coal, not minable	1	4.7	Low	Low
Clay—dark gray, carbonaceous, shaly	5	4.5	Low	Low
Sandstone—grayish brown, massive	13	5.8	Medium	Low
Shale—grayish to brown, silty, thin-bedded, hard, mixed with fragmental sandstone	22	6.1	High	Low
Coal—No. 7, Upper Freeport				

[1]Physical and chemical analyses of random sample areas in adjacent spoils are:

Area No.	Depth of sample Inches	Acidity (pH)	Available nutrients		Percent stone	Soil Fraction		
			Phosphorus	Potash		Sand	Silt	Clay
						Percent		
1	0-6	3.6	Medium	Low	59	——	——	——
	6-12	3.7	Medium	Low	59	——	——	——
	12-18	3.5	High	Low	65	——	——	——
2	0-6	6.2	High	Low	61	25.2	34.6	40.2
	6-12	6.6	Medium	Low	59	——	——	——
	12-18	6.5	High	Low	51	——	——	——
3	0-6	6.4	High	Low	82	40.8	29.2	30.0
	6-12	6.9	Medium	Low	81	——	——	——
	12-18	7.3	High	Low	76	——	——	——
4	0-6	6.4	Medium	Low	57	20.0	45.2	34.8
	6-12	6.4	Medium	Low	74	——	——	——
	12-18	6.4	High	Low	69	——	——	——
5	0-6	5.6	High	Low	59	——	——	——
	6-12	5.2	High	Low	57	——	——	——
	12-18	5.1	High	Low	52	——	——	——

Table 28.—**Description and chemical analyses of strata over the Mahoning coal seam, Section 15, Elk Run Township, Columbiana County, Ohio**

Description of strata (Top to bottom)	Thickness (Feet)	Acidity (pH)	Available nutrients	
			Phosphorus	Potash
Soil—dark gray-brown silt loam	0.5	4.9	Low	Low
Subsoil—gray-brown silt loam, with glacial stones and sandstone	1	4.8	Medium	Low
Shale—fine sandy to silty; brown, fragmental and thin-bedded	6	5.3	Medium	Low
Shale—gray-green, hard, thin-bedded, silty	12	5.3	Low	Low
Shale—blue - gray, slightly carbonaceous, hard, silty, slightly slaty	6	6.3	High	Low
Shale—blue-black roof-coal, slaty, carbonaceous, hard and bony	4	7.1	High	Low

Table 29.—**Description and chemical analyses of strata over the Mahoning coal seam, Section 24, Fairfield Township, Columbiana County, Ohio**

Description of strata (Top to bottom)	Thickness (Feet)	Acidity (pH)	Available nutrients	
			Phosphorus	Potash
Soil—gray silt loam	0.5	4.7	Low	Low
Glacial till—yellow - brown silty clay loam, with rounded stones	12	4.7	Low	Low
Shale—gray to greenish - gray, somewhat sandy but chiefly silty; thin-bedded and hard	4	6.7	Medium	Low
Shale—gray - black, carbonaceous, thin-bedded	8	7.4	High	Low
Shale—thick-bedded, silty but somewhat sandy; hard, massive	4	7.6	High	Low
Shale—gray-black, carbonaceous, slaty	2	7.7	Medium	Low

Table 30.—**Description and chemical analyses of strata over the No. 8 Pittsburgh coal seam, Section 30, Ames Township, Athens County, Ohio**

Description of strata (Top to bottom)	Thickness (Feet)	Acidity (pH)	Available nutrients	
			Phosphorus	Potash
Soil—gray silty clay loam	1	7.1	Low	Low
Clay—gray-green to brown, stiff, plastic, mixed with limestone fragments	2	8.1	Medium	Low
Clay—gray, in places shaly with coal fragments and limestone nodules. (Possibly the normal location for the Redstone coal seam).	2	8.1	Low	Low
Shale—green, clayey, thin - bedded and soapy; exposed surfaces ferruginous	8	8.1	Medium	Low
Shale—or clay, granular; gray with reddish-purple tinge	8	8.1	High	Low
Sandstone—gray, massive, somewhat shaly in lower foot, with occasional limestone nodules	8	8.3	Medium	Low
Shale—gray, silty at top, changing gradually to soft clay shale and then to dark, black roof coal	5	3.2	Low	Medium

Table 31.—**Description and chemical analyses of strata over the No. 8 Pittsburgh coal seam, Section 13, Short Creek Township, Harrison County, Ohio**[1]

Description of strata (Top to bottom)	Thickness (Feet)	Acidity (pH)	Available nutrients	
			Phosphorus	Potash
Soil—brown silty clay loam	1	5.9	Low	Low
Clay—partly shale, brown, blocky structure	3	5.6	Low	Low
Shale—clayey, gray-brown	15	6.6	Medium	Low
Shale—carbonaceous	1	5.8	Medium	Low
Limestone—reddish yellow, massive	27	——	High	Low
Shale—gray, hard, acidic, clayey, greasy	3	6.8	Medium	Low
Coal—Redstone, shaly	1	5.2	Low	Low
Limestone—reddish gray, massive	20	——	——	——
Shale—gray. mixed with limestone boulders	6	7.0	Low	Low

[1]Physical and chemical analyses of spoils located near high-wall sampling area were as follows:

Depth of sample Inches	Acidity (pH)	Available nutrients		Percent stone	Soil fraction		
		Phosphorus	Potash		Sand	Silt	Clay
					— — Percent — —		
0-6	7.9	Low	Medium	50	0-8	46.8	52.4
6-12	7.9	High	High	64	——	——	——
12-18	7.9	Medium	Low	61	——	——	——

Table 32.—**Description and chemical analyses of strata over the No. 8 Pittsburgh coal seam, Section 2, Wayne Township, Jefferson County, Ohio**[1]

Description of strata (Top to bottom)	Thickness (Feet)	Acidity (pH)	Available nutrients	
			Phosphorus	Potash
Soil—brown silt-loam, acidic	0.5	——	——	——
Clay—brown-gray, acidic	9	5.2	Low	Low
Shale—light gray, sandy and micaceous, mixed with sandstone fragments (sometimes massive)	6	4.7	Low	Low
Shale—gray-black, clayey, carbonaceous	14	6.2	High	Low
Coal—Redstone, shaly	1	4.9	Low	Low
Limestone—gray to yellow, massive in upper portion, remainder fragmental	20	8.3	Medium	Low
Shale—gray; clayey	4	8.2	Low	Medium

[1]Spoils near location of this sampling area were also analyzed. Results are as follows:

Depth of sample Inches	Acidity (pH)	Available nutrients		Percent stone	Soil fraction		
		Phosphorus	Potash		Sand	Silt	Clay
					— — Percent — —		
0-6	7.0	Low	Low	45	10.6	43.0	46.4
6-12	7.4	Medium	Low	55	——	——	——
12-18	7.7	Medium	Low	38	——	——	——

Table 33.—**Description of strata over the No. 9 Sewickley coal seam, Section 30, Short Creek Township, Harrison County, Ohio**

Description of strata (Top to bottom)	Thickness (Feet)
Soil—dark brown clay, acidic	1
Siltstone—yellowish brown, hard, calcareous	12
Limestone—yellowish, grading into glauconite in occasional parts of high-wall; calcareous	2
Shale—calcareous, mottled brown, platy, with some sandstone	8
Coal—No. 9, Sewickley	

Table 34.—**Description of strata over the No. 9 Sewickley coal seam, Section 3, Flushing Township, Belmont County, Ohio**

Description of strata (Top to bottom)	Thickness (Feet)
Soil—gray loam, acidic	0.5
Subsoil—mottled gray-green and yellow sandy clay	3
Shale—somewhat thick-bedded, sandy, slightly toxic, ferruginous; gray-green to brown	6
Sandstone—gray to brown, massive, acidic, with toxic ferruginous spots	2 to 6
Shale—gray-green, silty, thin-bedded, ferruginous, toxic	18
Coal—No. 9, Sewickley	

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